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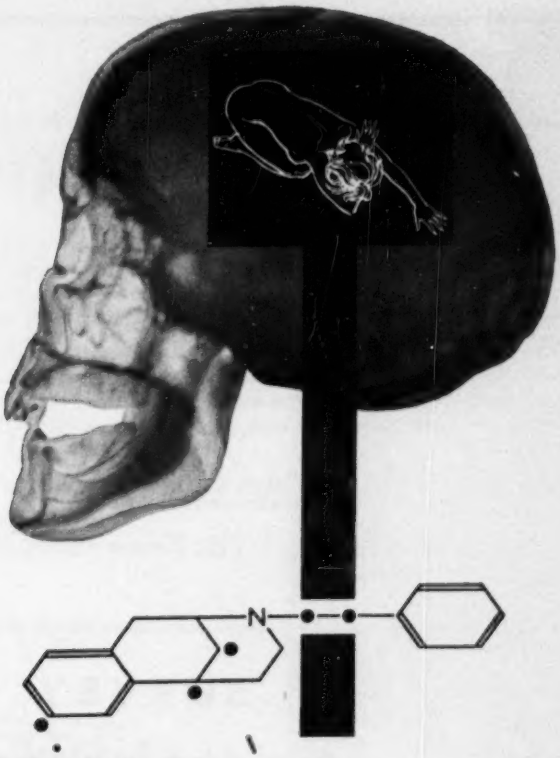

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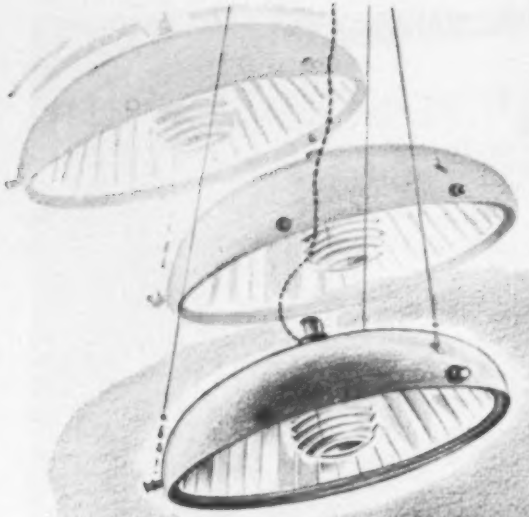

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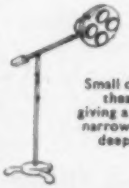

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BRITISH JOURNAL OF ANAESTHESIA

VOL. XXXII, No. 5 MAY 1960

EDITORIAL

A FACULTY OF ANAESTHETISTS IN THE ROYAL COLLEGE OF SURGEONS IN IRELAND

Recent notices in the medical press have announced the institution of a Faculty of Anaesthetists by the President, Vice-President and Council of the Royal College of Surgeons in Ireland. We would like to draw attention to the first scientific meeting to be organized by this Faculty (see page 246).

A Diploma in Anaesthetics has been granted by the Conjoint board of the Royal College of Physicians and Surgeons in Ireland since 1943. The regulations for this Irish diploma differ slightly from those of the English diploma and a longer period of whole-time practice of anaesthesia is required before candidates can sit for the examination. An alternative provision is made for part-time anaesthetists requiring the administration of "more than 600 anaesthetics", half of which must be major ones. Whereas the nature of the English diploma examination has changed twice since its inception in 1935 (and is now not an examination for consultant status), there has been no appreciable change in the nature of the Irish examination. With two papers and two orals, more attention is paid to the basic sciences, although no one would claim that it achieves the high standard of the F.F.A.R.C.S. examinations.

The objects and constitution of this newly formed Faculty are similar to those of its English predecessor which has been in existence for twelve years. Its first Board was elected by the Council of the Royal College of Surgeons in Ireland and it contains representatives from all the medical schools in the country. Once the foundation Fellows have been admitted, vacancies to the Board will be by nomination and election by these and subsequently admitted Fellows. It is proposed that Board members hold office for five years and are not eligible for re-election for another year. Representing, as it does, a much smaller community, the Irish Board of Faculty is not as large as its English counterpart.

With the limited state health service at present operating in the Republic of Ireland, it is often difficult for anaesthetic staff of voluntary hospitals to devote their whole time to the specialty. Circumstances necessitate that many of these supplement their incomes from private anaesthetic or even general medical practice. It is hoped that this recent recognition of the specialty by the College of Surgeons will both improve their standing among their colleagues and lead to better terms of service, thus encouraging more people to enter into the full-time practice of anaesthesia.

While divided politically, the Irish unite to play rugby, golf and hockey and it is pleasing to note this unity in the newly formed Faculty. At present the only full-time university appointments in Anaesthesia are in Northern Ireland (and these are only of recent origin). It is obvious that the Irish Board of Faculty is aware of this lack of organized postgraduate instruction since their opening venture is a scientific meeting dealing with one of the most basic topics—assessment of the depth of anaesthesia. The success of similar meetings in London is well known.

With the formation of the World Federation of Anaesthetic Societies and the interest which is being taken in the forthcoming World Congress in Toronto, it is becoming apparent that international relationships between anaesthetists are probably better than those of any other specialty. The Association of Anaesthetists of Great Britain and Ireland has always been representative of the whole of the British Isles and has representatives from both Northern Ireland and the Republic of Ireland on its present council. It is fitting that this latter representative, Dr. T. J. Gilmartin, should have been elected as the first Dean of the Irish Faculty. For many years Dr. Gilmartin has worked for the furtherance of the specialty in Eire, and has been an examiner for the Irish Diploma in Anaesthesia, and under his guidance one can be assured that the examination for the F.F.A.R.C.S.I. will be of the same high standard as that of the English College.

Brit. J. Anaesth. (1960), 32, 202

FURTHER STUDIES OF THE INFLUENCE OF CARBON DIOXIDE ON NEUROMUSCULAR BLOCKING AGENTS IN THE CAT*

BY

J. P. PAYNE

Department of Anaesthesia, Postgraduate Medical School and Hammersmith Hospital, London, W.12

IT has been previously established that the activity of the common neuromuscular blocking agents in the cat is modified by the administration of carbon dioxide. It was found that carbon dioxide opposed the action of suxamethonium, decamethonium and gallamine, but enhanced the activity of tubocurarine (Payne, 1958). This effect has not been fully explained and it was thought that the examination of other less common relaxants under the same circumstances might prove helpful in determining the mode of action. Accordingly two drugs once in clinical use, benzoquinonium (Mytolon) and laudexium (Laudolissin) as well as two new tropane derivatives D.F.596 and D.F.648 (Haining et al., 1959), still undergoing trial, were investigated.

METHOD

The sciatic nerve-anterior tibialis muscle preparation in the intact cat (Brown, 1938) was used to study the effects of the drugs in the presence of 5 per cent carbon dioxide. A detailed description of the method employed has been published previously (Payne, 1958). The drugs were administered by the divided dose technique recommended by Paton (personal communication) and described elsewhere (Payne and Rowe, 1957). In a series of eleven cats, the effect of benzoquinonium was studied in two, while the actions of laudexium, D.F.596 and D.F.648 were investigated in three each. In the study of the tropane derivatives soleus muscle activity was also examined.

RESULTS

Benzoquinonium.

In the two cats studied, the administration of 5 per cent carbon dioxide antagonized the neuromuscular blocking properties of benzoquinonium as shown in figure 1. From the same figure it can be seen that this antagonism developed despite a 20 per cent reduction in the size of the muscle twitch during the administration of carbon dioxide before the drug was injected. It is also obvious that, although the neuromuscular block was less effective under the influence of carbon dioxide, the recovery process was slower.

Laudexium.

The influence of carbon dioxide on laudexium was investigated in three cats, in none of which was there any evidence of either antagonism or enhancement. In one, however, there was a slight delay in the recovery time of the muscle twitch during the administration of carbon dioxide (fig. 2).

D.F.596.

In the three cats given D.F.596 there was definite evidence of an enhanced effect of the drug on both the anterior tibialis and soleus activity in the presence of 5 per cent carbon dioxide (fig. 3). Again it was noted that when the drug was used during the administration of carbon dioxide, the development of neuromuscular block was more gradual and the recovery process slower than during the control period.

D.F.648.

The influence of carbon dioxide on D.F.648 followed closely the pattern established for D.F.596. In the three animals studied the enhanced effect in the presence of carbon dioxide was unequivocal (fig. 4).

When the tropane derivatives were used to obtain neuromuscular block, the anterior tibialis was considerably more sensitive to their action than was soleus (figs. 3 and 4).

* Work done in the Pharmacological Department, Royal College of Surgeons of England.

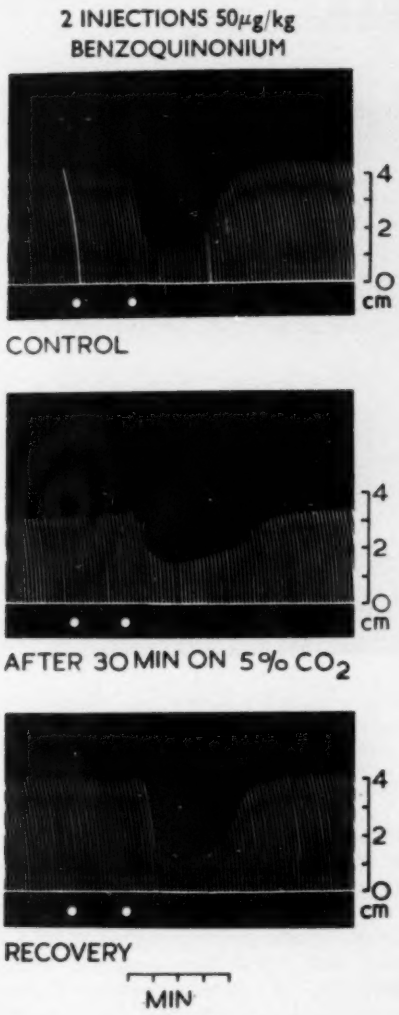

FIG. 1

Sciatic nerve—tibialis anterior muscle preparation in the intact cat. The tracings show the development of resistance to the action of benzoquinonium on exposure to carbon dioxide with subsequent return of the normal response when carbon dioxide is withdrawn. Note (*a*) the reduction in size of the muscle twitch and (*b*) the more prolonged recovery time during exposure to carbon dioxide.

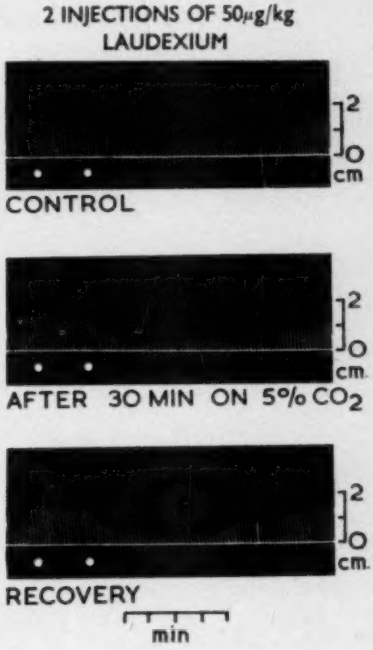

FIG. 2

Sciatic nerve—tibialis anterior muscle preparation in the intact cat. The extent of neuromuscular block is uninfluenced by the presence of carbon dioxide but both the onset of block and the recovery process is delayed.

DISCUSSION

The weak action of benzoquinonium in the presence of carbon dioxide supports the earlier impression that most relaxants are antagonized by this gas, but the demonstration of an increase in the neuromuscular blocking activity of the tropane derivatives when carbon dioxide is inhaled has only added to the difficulties of interpretation. Two other drugs, mecamylamine and d-tubocurarine chloride, the myoneural blocking actions of which are enhanced by carbon dioxide (Payne and Rowe, 1957; Payne, 1958), both have pK values within the physiological range and are therefore liable to alteration in their degree of dissociation with changes in blood pH (Albert, 1952). Originally this was thought to explain the response obtained with these two drugs in the presence of carbon dioxide (Payne,

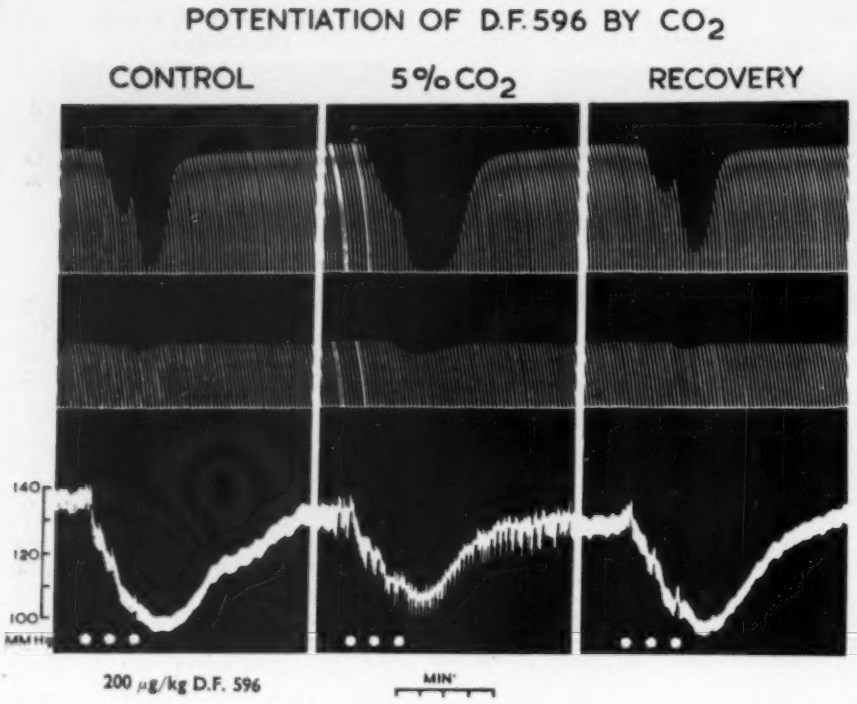

FIG. 3

Sciatic nerve—tibialis anterior and soleus muscle preparations in the intact cat; blood pressure. The action of D.F.596 is enhanced in the presence of carbon dioxide. Note the hypotensive effect of each intravenous injection.

1959), but doubt was thrown on the adequacy of the explanation by the demonstration that if the blood pH was lowered by the intravenous infusion of acid the action of tubocurarine was weakened (Payne, 1960). The demonstration here that both tropane derivatives are enhanced in the presence of carbon dioxide is further proof that changes in drug ionization are unnecessary for the development of this effect, as it is unlikely that exposure to carbon dioxide can influence the dissociation of those substances (Haining, personal communication).

The failure to demonstrate any change in the activity of laudexium when exposed to carbon dioxide probably should not be accepted as conclusive. Only three animals were studied and the concentration of carbon dioxide employed was never raised above 5 per cent. Possibly had a higher concentration been used some change might have been obtained.

The more gradual onset of neuromuscular block and the slower recovery process during exposure to carbon dioxide could be related to the reduction in limb blood flow associated with the accumulation of carbon dioxide (Holmdahl, 1956) but this explanation is difficult to reconcile with the conflicting action of carbon dioxide on different relaxant drugs.

SUMMARY

The influence of carbon dioxide on the neuromuscular blocking properties of benzoquinonium, laudexium and two tropane derivatives has been studied.

The action of benzoquinonium is antagonized by carbon dioxide; the effect of tropane deri-

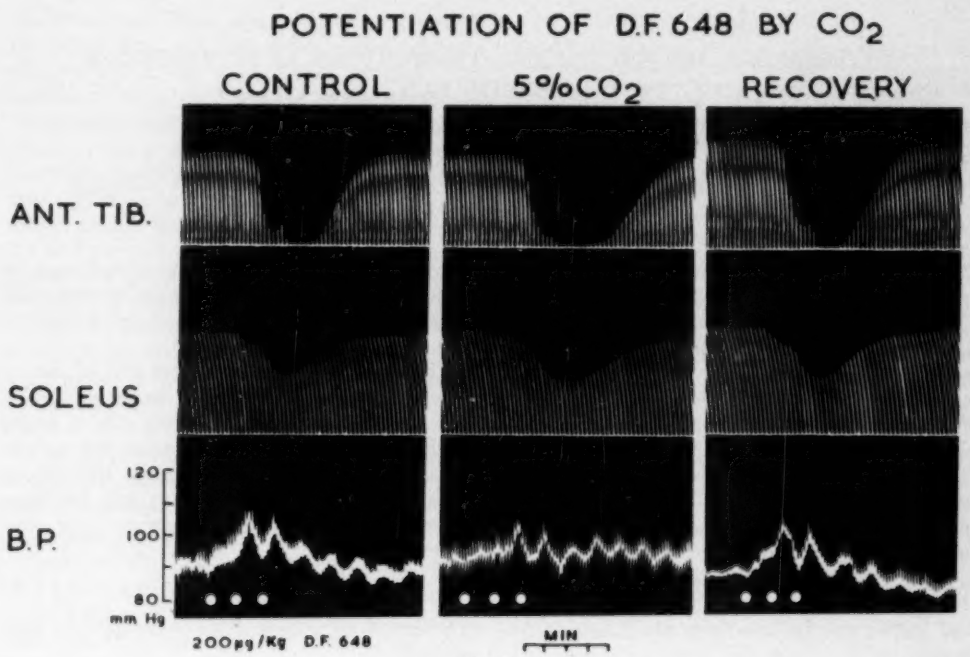

FIG. 4

Sciatic nerve—tibialis anterior and soleus muscle preparations in the intact cat; blood pressure. The action of D.F.648 is enhanced in the presence of carbon dioxide. Note the slight hypertensive effect of each intravenous injection.

vatives is enhanced and that of laudexium is unchanged.

No satisfactory explanation for these different observations is as yet available.

ACKNOWLEDGMENTS

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Able technical assistance was provided by Mrs. Dawn Gardiner, Mr. D. A. Green and Mr. R. Tennant.

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A COMPARISON OF INACTIN AND THIOPENTONE AS INTRAVENOUS ANAESTHETICS

BY

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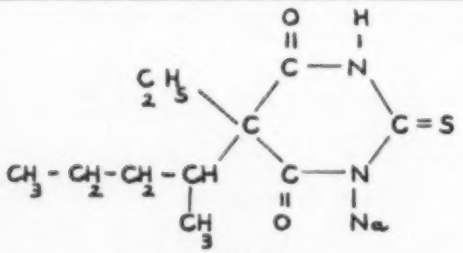
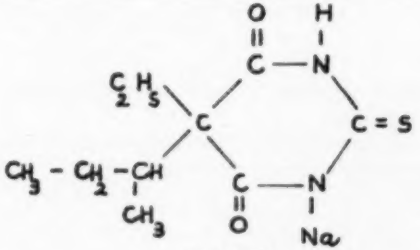
OF the large number of thiobarbiturates originally synthetized and described by Tabern and Volwiler (1935), thiopentone sodium has received widest acceptance in intravenous anaesthesia. Thiamylal enjoys a limited popularity in North America, but is not commercially available in this country. More recently, Nieschulz (1954) examined the pharmacological properties of sodium, 5-ethyl-5-(1-methyl-propyl)-thiobarbiturate and suggested its suitability for clinical use. This drug, known as inactin sodium, was introduced into anaesthetic practice by Horatz and Sturtzbecher (1952) and is much used in Germany.

The chemical similarity between thiopentone and inactin can be seen from the following formulae.



THIOPENTONE



INACTIN

Both drugs are soluble in water and are prepared for injection in a buffered solution with 6 per cent sodium carbonate. The pH of aqueous solutions of inactin is similar to that of thiopentone in equivalent concentration.

Published reports* suggest that inactin closely resembles thiopentone in its action, but it is slightly less potent. To date there have been no reports on its use in this country and no controlled comparisons of its actions with those of thiopentone.

This paper describes a clinical trial of inactin in which it was attempted, as far as possible to remedy this deficiency. The purely clinical nature of the evaluation is stressed, since the authors are satisfied from published reports that inactin is as safe a drug as thiopentone and may even possess some theoretical advantages over thiopentone.

PLAN OF TRIAL

The data to be presented can be divided into three sections.

(1) A comparison of the actions of the two drugs used in random order in an unselected series of cases.

(2) A detailed study of their induction characteristics in closely similar groups of cases.

(3) A "double blind" comparison of their actions in two comparable series of patients.

RANDOM USE OF DRUGS

The two drugs were used at random in all cases anaesthetized by the authors over a period of

* The complete bibliography on inactin is written in German and will not be discussed in detail, but for the benefit of readers who may be interested, a list of the most useful papers is appended to this paper.

about one year. There was no selection of patients for either drug and the choice depended upon the one which was most readily available. Pre-anaesthetic medication was not standard throughout the series and varied from atropine or hyoscine alone, to either of the drugs in combination with morphine, pethidine, papaveretum or promethazine. Thiopentone and inactin were injected intravenously. Each drug was given in either a 2.5 or 5 per cent solution and there was no selection as to which strength of solution was employed —about half the administrations being with each.

Special forms were designed for the recording of data throughout the study and these facilitated easier noting of those facets of the induction which are of particular interest to the clinical anaesthetist.

For the purpose of presentation and recording of data, the anaesthetic techniques employed have been grouped as follows.

Thiobarbiturate as main narcotic (M).

Induction with one or other of the thiobarbiturates followed by nitrous oxide-oxygen and supplementary doses of the thiobarbiturate as required. Suxamethonium was used for endotracheal intubation where necessary.

Thiobarbiturate as basal narcotic (*B*).

Thiobarbiturate induction followed by nitrous oxide-oxygen and a volatile agent (ether or trichloroethylene) or by cyclopropane and oxygen. Relaxants used as in M above.

Relaxant sequence (*R*).

Thiobarbiturate induction, followed by nitrous oxide-oxygen and a long acting muscle relaxant (tubocurarine or gallamine), with controlled respiration. Supplementation with intravenous analgesics as required.

The number of patients in each of these groups and their physical characteristics are shown in table I. The age distribution in each series is shown in figure 1. Table II lists the nature and duration of the operations performed and shows that each drug was used for a wide variety of surgical procedures of varying duration and severity.

TABLE I

Details of numbers of cases anaesthetized with each anaesthetic technique and physical characteristics of patients concerned. Physical status is classified according to the groups recommended by the American Society of Anesthesiologists (Dripps, Eckenhoff and Vandam, 1957).

Technique		Inactin	Thiopentone
M.	No. of cases	187	346
	Males	46	105
	Females	141	241
	Average age (yrs.)	37.6	40.1
	Physical status 1	164	324
	2	16	19
	3+	7	3
B.	No. of cases	344	361
	Males	121	122
	Females	213	239
	Average age (yrs.)	38.7	40.2
	Physical status 1	307	331
	2	31	29
	3+	6	1
R.	No. of cases	107	102
	Males	58	60
	Females	49	42
	Average age (yrs.)	50.9	47.2
	Physical status 1	75	68
	2	27	25
	3+	5	9

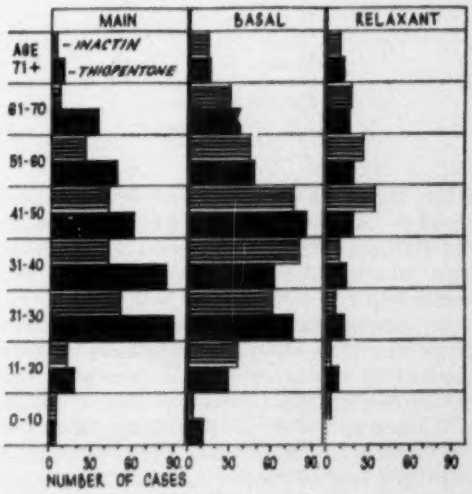


FIG. 1

Age distribution of patients anaesthetized with inactin and thiopentone. Anaesthetic techniques as outlined in text.

RESULTS

Inactin proved to be an effective drug for the rapid induction of anaesthesia by the intravenous route.

TABLE II

Nature and duration of operations.

Drug	Inactin			Thiopentone		
Technique	M	B	R	M	B	R
Total number of patients	187	344	107	346	361	102
Nature of operation						
General surgery						
Upper abdominal	—	—	41	—	—	32
Lower abdominal	—	3	19	—	10	14
Herniae	—	2	13	1	3	26
Others	15	57	—	37	57	—
Gynaecology						
Major	3	26	11	2	10	7
Minor	99	52	—	189	79	—
Neurosurgery						
Major	1	3	—	1	7	—
Minor	1	8	—	1	7	—
Urology						
Major	5	11	17	7	11	14
Minor	27	29	—	29	41	—
Orthopaedics						
Major	1	75	3	7	42	2
Minor	7	12	—	3	8	—
Otorhinolaryngology						
Major	—	20	—	—	28	—
Minor	—	2	—	—	2	—
Thoracic surgery						
Major	—	—	3	—	—	5
Minor	—	4	—	11	6	2
Dental extractions	4	40	—	26	50	—
Electroconvulsive therapy	24	—	—	32	—	—
Duration of operations						
0–10 min	101	97	—	212	137	—
11–30 min	68	124	4	95	104	5
31–60 min	10	65	30	24	53	23
61–120 min	7	43	52	10	51	45
121–180 min	1	15	18	5	14	18
181+ min	—	—	3	—	2	11

When maximum forearm blood flow was produced by means of reactive hyperaemia (Dundee and McArdle, 1959) the rate of onset of anaesthesia from effective doses of the two drugs was similar (fig. 2).

An accurate assessment of the relative potencies of the two drugs was not possible from the data obtained in this study but the impression was formed that inactin is about two-thirds as potent as thiopentone. When given in dosage similar to that required for thiopentone, inactin produced a very light level of narcosis from which patients would waken readily if stimulated and which frequently gave rise to a very violent response when a face mask was applied or a pungent vapour was added to the anaesthetic mixture. This phenomenon of light sleep was seen very commonly in the early stages of the trial but less frequently when the authors had become familiar with the characteristics of the drug.

The incidence of complications (other than cardiovascular) recorded during the induction period with the two drugs is shown in table III. The cases analyzed do not include those undergoing electroconvulsive therapy or short dental extractions and, for obvious reasons, the patients who received long acting muscle relaxants are not included. From this table it can be seen that little difference was found between the effects of the two drugs. In more recent cases the finding of a higher incidence of complaints of taste in the mouth with inactin has not been verified

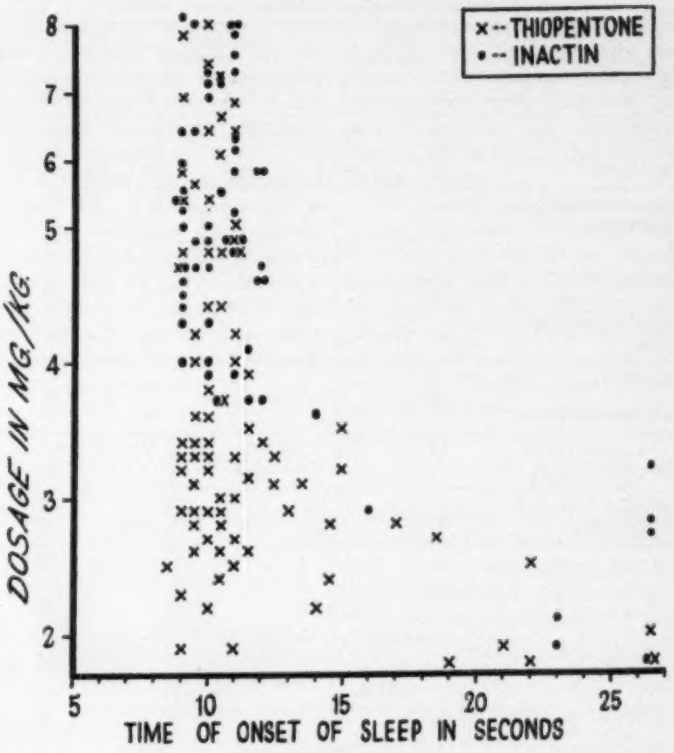


FIG. 2

Comparison of rate of onset of anaesthesia with thiopentone and inactin. Dose was injected over 5 seconds, about half a minute after release of an arterial tourniquet which was applied for 2½–3 minutes. Onset was measured from the end of the injection until the patient stopped counting.

and it is possible that this finding (table III) may have been due to inadequate dosage. More information on this crude data in table III will be presented in the next section.

It was necessary to limit the study of the cardiovascular effects of the two drugs to those patients who received a single injection of 5–6 mg/kg thiopentone or 6–8 mg/kg inactin and to exclude patients who were not of physical status 1 or 2 (classification of the American Society of Anaesthesiologists, see Dripps, Eckenhoff and Vandam, 1957), or who received a phenothiazine as premedication. The incidence of maximum blood pressure and pulse rate changes observed during the induction of anaesthesia is shown in table IV and figure 3. For the sake of simplicity in tabulating data the following conventions were adopted in table IV:

Normotensive subjects—systolic blood pressure under 160 mm Hg.

No blood pressure fall—systolic fall not exceeding 10 mm Hg.

Severe hypotension—systolic pressure fall in excess of 40 mm Hg.

Apart from a slightly higher incidence of moderate hypertension following inactin in normotensive subjects (technique M), the effects of the two drugs on the blood pressure did not differ greatly. This slight difference may be due to the greater care which was involuntarily taken when recording the effects of the unfamiliar drug. It is more difficult to assess the significance of the

TABLE III

Incidence of complications, other than cardiovascular, occurring during the induction period and details of patients studied.

Technique	Main narcotic		Basal narcotic		Total	
Drug	I	T	I	T	Inactin	Thiopentone
Number of cases	159	346	304	361	463	707
% Males	26	30	35	34	32	32
Average age (yrs.)	37.6	40.1	38.0	40.2	38.0	40.2
Respiratory complications						
Marked depression	—	6	9	9	9	15
Coughing	11	4	4	10	15	14
Hiccough	1	3	6	6	7	10
Laryngospasm—mild	5	7	4	5	9	12
—severe	2	2	—	1	2	3
Percentage with no respiratory complications	91	94	90	90	91	93
Muscle movements						
Tremor	4	5	6	2	10	7
Involuntary movements	6	10	19	24	25	34
Complaint of taste in mouth	13	6	14	8	27	14
Unusual resistance to drugs	2	3	2	4	4	7
Complete absence of any of above complications	80%	82%	91%	84%	87%	83%

TABLE IV

Cardiovascular effects of the induction period.

	Main narcotic		Basal narcotic		Total	
	I	T	I	T	Inactin	Thiopentone
Number of cases studied	93	165	81	179	164	344
Normotensive subjects	78	135	54	141	132	276
No B.P. fall	48 (60%)	104 (77%)	44 (80%)	115 (81%)	92 (70%)	219 (80%)
Moderate fall						
Recovered in 15 min	29	24	10	21	39	45
Recovery 15 min+	—	5	—	2	—	7
Severe fall						
Recovered in 15 min	1	1	—	1	1	2
Recovery 15 min+	—	1	—	2	—	3
Active treatment needed	—	1	—	—	—	1
Hypertensive subjects	15	30	27	39	42	69
No B.P. fall	6 (40%)	13 (43%)	17 (63%)	18 (46%)	23 (45%)	31 (45%)
Moderate fall						
Recovered in 15 min	6	9	8	10	14	19
Recovery 15 min+	3	1	—	—	3	1
Severe fall						
Recovered in 15 min	—	5	1	7	1	12
Recovery 15 min+	—	2	1	4	1	6
Active treatment needed	—	1	—	2	—	3
Very alarming depression of circulation	—	1	—	1	—	2

higher incidence of profound hypotension after thiopentone as compared with inactin. This difference was apparent in both the normotensive and hypertensive subjects and it can be seen that the use of vasopressors was needed in three patients who received thiopentone.

For simplicity, the incidence of maximum changes in pulse rate (fig. 3) is expressed as a percentage of the total number of observations. Thiopentone appeared to have a greater tendency to cause marked increases in pulse rate than inactin. On further analysis of the data it was found that severe tachycardia occurred in those patients in whom hypotension was either marked in extent or prolonged in duration.

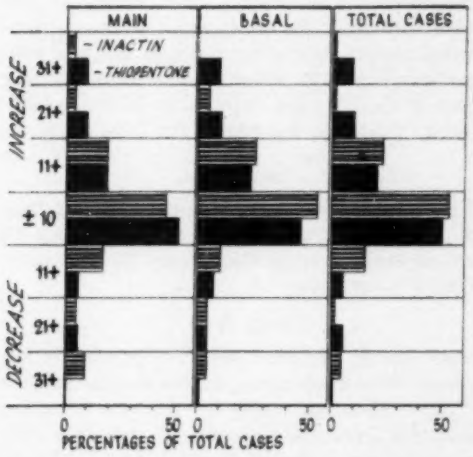


FIG. 3

Percentage incidence of pulse rate changes (beats/min) following induction of anaesthesia with thiopentone (5–6 mg/kg) and inactin (6–8 mg/kg) in patients described in table IV.

One death during anaesthesia occurred with each drug but in neither instance was there any reason to suppose that the anaesthetic agent played any part in the fatality.

With the relaxant sequence (R) there was no case of prolonged curarization with either drug and there was no evidence that the synergism of inactin with either type of muscle relaxant differed from that of a comparable dose of thiopentone.

Exact data on the comparable rate of recovery from the two drugs cannot be obtained from this study. There were no cases of delayed return of consciousness with either drug and an impression was formed that the duration of narcosis with inactin was similar to that with comparable doses of thiopentone.

No patients complained of pain on injection during this study. Although they were not followed up in detail for the occurrence of venous thrombosis, there was no report of this as a major complication of the postoperatve period. A small volume of 2.5 per cent solution was accidentally injected subcutaneously on three occasions with each drug. The injection site was infiltrated with procaine and hyaluronidase and there were no undesirable sequelae.

DISCUSSION

The limitations of this data are fully appreciated. It is realized that factors other than the drug under study must be taken into consideration in making strict comparisons of the effect of anaesthetic agents. Nevertheless, this part of the trial established that inactin is a safe, reliable and acceptable drug for routine use as an induction agent.

DETAILED STUDY OF INDUCTION CHARACTERISTICS

The object of this study was to examine, in comparable series of cases with each drug, the incidence of certain undesirable complications which occurred immediately following the injection of the thiobarbiturate and which, it could be reasonably assumed were caused by the drug. An action not observed until the introduction of a supplementary drug (except nitrous oxide and oxygen) was not recorded.

Observations were limited to those shown in table III and, for the sake of analysis, are grouped as follows:

Excitatory phenomena:

Tremor and spontaneous involuntary movements of limbs.

Respiratory upset:

Cough hiccough, laryngospasm or marked respiratory depression. This latter was taken as apnoea or depression of such duration that active measures were needed to maintain oxygenation.

Data on the initial and total doses of thiobarbiturates needed for the induction of anaesthesia were also recorded. Blood pressure and pulse rate changes were not analyzed in detail, but the occurrence of hypotension was taken into consideration when assessing the "grade of induction" (q.v.).

As a means of comparing directly the actions of the two drugs and to make allowance for all the above complications the induction of anaesthesia in each patient was graded as follows:

(1) Smooth uncomplicated induction.

(2) Slight upset during the induction period, but which was not marked as in grade 3.

(3) Serious difficulties making surgery impossible or placing the patient's life in jeopardy (including severe, prolonged hypotension).

The cases included in this study are, in the main, the same as those that were in the first part, but because of lack of precise data and for other reasons, the records of 120 of the inactin group and 150 who received thiopentone (with techniques B and M) had to be discarded. An additional 68 administrations of inactin and 110 of thiopentone are included in the final total.

It was essential that the above mentioned facets of the induction period with inactin and thiopentone should be compared in strictly comparable series of patients. However, information concerning the factors (other than the agent under study) which might influence the incidence of complications during the induction period is lacking and an analysis of the effect of five possible variables was carried out. These were:

Sex.

Age (45 years and under compared with those patients over 45 years).

Physical status (grades 1 and 2 compared with 3 and 4).

Presence or absence of an opiate (pethidine, morphine and papaveretum) in the pre-anaesthetic medication.

Use of long acting muscle relaxants (since a test dose of these was frequently injected before the thiobarbiturate).

The appendix gives the findings of this analysis and this shows that the results to be presented are based on strictly comparable series of patients.

RESULTS

The incidence of complications following the induction of anaesthesia in all patients of physical status 1 and 2 who did not receive a long acting muscle relaxant is set out in table V. It can be seen that there was no significant difference between the effects of the two drugs. Table VI shows a comparison of the incidences of different grades of induction in ten comparable series of cases. Where a statistical comparison of these effects was possible (with or without pooling series) it revealed no differences between the drugs.

A comparison of the average induction doses (table VII) confirms a previously stated impression that inactin was significantly less potent than thiopentone. The potency ratio shown in this table is what might be expected from the published reports. It can be seen also that the proportion of cases in whom a small supplementary dose of the drug was required to achieve a satisfactory induction was similar for both drugs.

DISCUSSION

This study confirms, in all respects, the findings of the previous section and shows that inactin was as satisfactory as thiopentone for the induction of anaesthesia.

BLIND TRIAL

Since inactin has been shown to be slightly less potent than thiopentone, it was decided to find if this difference could be detected clinically. Identical 1-gramme ampoules of each drug were prepared, the contents of which were unknown to the administrators. Several anaesthetists other than the authors, co-operated in this trial and the findings (table VIII) are based on those patients who received the thiobarbiturates with nitrous oxide-oxygen for minor surgical procedures. Participants were asked to identify the drug being used. The incidence of correct identification of thiopentone is significantly greater than for inactin. However, in more than 90 per cent of the administrations of the latter drug it was recorded that thiopentone was not being used.

Although the differences between the incidence of complications with the two drugs is not statistically significant, a comparison of tables III, V,

TABLE V

Comparison of incidence of side effects during induction of anaesthesia with inactin and thiopentone in comparable series of cases.

Premedication	Opiate			Non-opiate		
	Inactin	Thiopentone	Significance of difference	Inactin	Thiopentone	Significance of difference
Total cases	266	399		145	268	
Excitatory phenomena						
Tremor	6	6	$0.3 > P > 0.2$	8	7	$0.1 > P > 0.05$
Involuntary limb movements	13	14	$0.5 > P > 0.3$	16	19	$0.3 > P > 0.2$
Percentage with none of above	94	96	$0.1 > P > 0.05$	86	91	$0.1 > P > 0.05$
Respiratory disturbances						
Cough hiccough	6	1		11	8	$0.1 > P > 0.05$
Laryngospasm	9	8	$0.5 > P > 0.3$	3	2	
Percentage with none of above	95	98	$0.1 > P > 0.05$	92	92	$0.7 > P > 0.5$
Percentage incidence of marked respiratory depression	3.3	5.5	$0.5 > P > 0.3$	4.0	1.2	

TABLE VI

Comparison of the incidence of various "grades of induction" with Inactin (I) and thiopentone (T) in several comparable groups of patients.

Technique	Non-relaxant																Relaxant			
Premedication	Opiate								Non-opiate								Opiate		Non-opiate	
Age group	15—45				46+				15—45				46+							
Sex	F		M		F		M		F		M		F		M					
Drug	I	T	I	T	I	T	I	T	I	T	I	T	I	T	I	T	I	T	I	T
Number of cases	140	202	67	86	28	37	31	74	73	104	40	70	20	61	12	33	48	61	47	38
Grade of induction 1	125	186	61	82	24	33	28	66	62	86	30	62	14	54	11	29	47	58	44	33
2	9	13	5	4	4	4	2	7	11	16	9	7	5	7	1	3	1	2	3	5
3	6	3	1	0	0	0	1	1	0	2	1	1	1	0	0	1	0	1	0	0
% Grade 1	90	92	91	95	86	90	90	89	85	82	75	89	70	89	91	92	98	95	94	86
χ^2	2.59		1.22						0.47		2.52								2.34	
Significance	0.2> P>0.1		0.3> P>0.2						0.5> P>0.3		0.2> P>0.1								0.2> P>0.1	
χ^2					0.24								1.21							
Significance					0.7>P>0.5								0.3>P>0.2							
χ^2	0.35								0.22								1.42			
Significance	0.7>P>0.5								0.5>P>0.3								0.3>P>0.2			

TABLE VII

Average doses of inactin and thiopentone used for induction of anaesthesia in comparable groups of patients.
(Criteria for cases are as for table V.)

Series	Inactin			Thiopentone			Difference	
	No. of cases	% repeat dose	Average induction dose (mg/kg)	No. of cases	% repeat dose	Average induction dose (mg/kg)	Significance of difference	Ratio Thiopentone / Inactin
Opiate premedication								
Females	140	27.9	6.79 ± 0.15	202	33.2	5.18 ± 0.10	$t = 5.75$, $P < 0.001$	0.77
Males	67	26.9	7.21 ± 0.25	86	30.2	5.30 ± 0.22	$t = 8.134$, $P < 0.001$	0.74
Non-opiate premedication								
Females	73	27.4	6.82 ± 0.41	204	23.1	5.63 ± 0.15	$t = 4.762$, $P < 0.001$	0.83
Males	40	42.5	7.13 ± 0.32	70	38.6	5.79 ± 0.39	$t = 4.330$, $P < 0.001$	0.81

TABLE VIII

Comparison of inactin and thiopentone where nature of drug was not known at time.
(All physical status 1—2 : 15—45 age group.)

	Inactin	Thiopentone	Significance of difference
Total number of cases	81	81	
Opiate—premedication	56	56	
Incidence of excitatory phenomena	10	5	$\chi^2 = 1.84$, $0.2 > P > 0.1$
Respiratory upsets (total incidence)	8	3	$\chi^2 = 2.44$, $0.2 > P > 0.1$
Respiratory depression	5	7	$\chi^2 = 0.56$, $0.5 > P > 0.3$
Grade of induction 1	64	71	$\chi^2 = 2.18$, $0.2 > P > 0.1$
2+3	17	10	
Guess at nature of drug used (44)			
Correct	31	40	$\chi^2 = 6.16$, $0.02 > P > 0.01$
Opposite drug	4	2	
Completely different drug	9	2	

and VIII shows that with both thiopentone and inactin they are much higher than when the administrator knew the nature of the drug being given. This throws doubt on the validity of data based on "blind" studies except when strictly equipotent solutions are used.

It was useful to confirm that the lesser potency of inactin as compared with thiopentone could be easily detected, but, apart from this, no additional information was obtained from this study.

SUMMARY AND CONCLUSIONS

A clinical study of the use of sodium, 5-ethyl, 5'-(1-methyl propyl) thiobarbiturate (inactin), in 745 patients is presented. Results are compared with those of thiopentone administered to 1,000 patients.

Apart from the finding that inactin is only about three-quarters to four-fifths as potent as thiopentone (W/W), no significant differences in the actions of the equipotent doses of the drugs could be detected.

The authors conclude that inactin is as satisfactory as thiopentone for routine use in the induction of anaesthesia.

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APPENDIX

A STUDY OF FACTORS LIKELY TO INFLUENCE THE INCIDENCE OF COMPLICATIONS FOLLOWING INDUCTION OF ANAESTHESIA WITH THIOPENTONE AND INACTIN

Based on the five factors outlined previously, 32 potential groups of patients were possible. The paucity of numbers reduced this to 23 groups and in some of these the number of cases was so small as to make comparisons impossible. This applied particularly to patients who received long-acting muscle relaxants and these are considered separately later.

The data to be presented are based mainly on the incidence of various grades of induction (table VI), but similar analyses have been carried out on the incidence of excitatory phenomena and respiratory side effects. This will be presented only when it throws any further light on the subject.

Sex.

The significance levels between the incidence of grade I induction in the two sexes in non-relaxant cases of physical status 1 and 2 is shown in table IX. It is unlikely, from these findings, that the sex of the patient plays any part in determining the incidence of induction complications.

Age.

A similar analysis for the difference between the two age groups, using the same selection of cases as for sex, is shown in table X. This shows that the age per se is not an important factor in patients of physical status 1 and 2.

TABLE IX

Significance levels between incidence of Grade I induction in the two sexes

All non-relaxant cases, good physical status.

		Probability
Thiopentone		
Age 15—45	Opiate premedication	$0.20 > P > 0.10$
	Non-opiate	$0.30 > P > 0.20$
Age 46+	Opiate premedication	$0.50 > P > 0.30$
	Non-opiate	$0.70 > P > 0.50$
Inactin		
Age 15—45	Opiate premedication	$0.70 > P > 0.50$
	Non-opiate	$0.10 > P > 0.05$
Age 46+	Opiate premedication	$0.50 > P > 0.30$
	Non-opiate	data not suitable for analysis
Difference between females and pooled sexes in above group		$0.40 > P > 0.05$

TABLE X

Significance level of difference between incidence of Grade I induction in different age groups.

Non-relaxant : good physical status.

Thiopentone		Probability
Opiate premedication :	Females	$0.70 > P > 0.50$
	Males	$0.20 > P > 0.10$
Non-opiate	Females	$0.10 > P > 0.05$
	Males	$0.50 > P > 0.30$
Inactin		
Because of paucity of numbers the significance was calculated between young age group (15–45) and pooled data from all ages.		
Opiate premedication :	Females	$0.70 > P > 0.50$
	Males	$0.70 > P > 0.50$
Non-opiate	Females	$0.50 > P > 0.40$
	Males	$0.70 > P > 0.50$
It was not possible to carry out a similar comparison with the elder age group.		
Comparison of age groups in series with sexes pooled.		
Opiate premedication		$0.10 > P > 0.05$
Non-opiate premedication		$0.70 > P > 0.50$

Pre-anaesthetic medication.

The influence of the addition of an opiate to the pre-anaesthetic medication in good risk cases who did not receive a long acting muscle relaxant is examined in table XI. While the differences between the incidence of grade 1 induction only once reached a 5 per cent significance level they are so marked that they cannot be ignored. This is illustrated in table V which shows that, with both drugs, there was a higher incidence of excitatory phenomena in the patients who received atropine alone before the induction of anaesthesia. The significance between the opiate and non-opiate series referred to above is:

Thiopentone	$=\chi^2=11.75$	$0.01>P>0.001$
Inactin	$=\chi^2=9.03$	$0.01>P>0.001$

The use of opiates did not significantly influence the incidence of respiratory disturbances with inactin but the effect was very marked with thiopentone ($0.01>P>0.001$).

This shows that a strict attention must be paid to the pre-anaesthetic use of opiates when comparing the incidence of complications following the intravenous induction of anaesthesia. At no time were opiate and non-opiate cases pooled in tables V and VI.

Physical status.

By virtue of the nature of the A.S.A. classification, it is obvious that patients in classes 1 and 2 can be justifiably pooled for the purpose of analysis. The number of class 3 and 4 patients in this study was very small, but when these are pooled, irrespective of age or sex, the incidence of grade 1 inductions was as follows:

Thiopentone	: opiate premedication	81%
Inactin	: opiate premedication	77%
Thiopentone	: non-opiate premedication	65%
Inactin	: non-opiate premedication	60%

TABLE XI

Difference between opiate and non-opiate premedication. Probability of the difference between these factors affecting the grade of induction having arisen by chance.

Thiopentone		Probability
15—45 Age group :	Females	$0.02 > P > 0.01$
	Males	$0.10 > P > 0.05$
46+ Age group :	Females	$0.70 > P > 0.50$
	Males	$0.70 > P > 0.50$
Pooled ages and sexes		$0.20 > P > 0.10$
Inactin		
15—45 Age group :	Females	$0.30 > P > 0.20$
	Males	$0.10 > P > 0.05$
46+ Age group :	Pooled sexes	$0.10 > P > 0.05$

TABLE XII

Analysis of comparison of relaxant and non-relaxant cases. Good physical status cases only : pooled sexes and ages.

Series	χ^2	Probability
Opiate premedication		
Thiopentone	1.10	$0.30 > P > 0.20$
Inactin	5.12	$0.05 > P > 0.02$
Non-opiate premedication		
Thiopentone	0.13	$0.80 > P > 0.70$
Inactin	4.74	$0.05 > P > 0.02$

TABLE XIII

Significance of difference between mean induction dosage in different sexes.

(Same patients as for table VII).

Premedication	Drug	t	df	P
Opiate	Thiopentone	0.710	286	$0.5 > P > 0.3$
	Inactin	2.065	205	$0.05 > P > 0.01$
Non-opiate	Thiopentone	0.732	172	$0.5 > P > 0.3$
	Inactin	0.984	111	$0.4 > P > 0.3$

TABLE XIV

Significance of the difference in mean induction doses of the two drugs in opiate and non-opiate cases.

(Physical status 1 and 2 : non-relaxant technique).

Drug	Sex of patients	t	df	P
Thiopentone	Females	3.048	304	$0.01 > P > 0.001$
	Males	1.805	134	$0.10 > P > 0.05$
Inactin	Females	0.0014	211	$P > 0.90$
	Males	0.028	105	$P > 0.90$

These percentages are so much lower than those shown in table VI for similar patients of class 1 and 2, that it is obvious that physical status is an important factor in influencing the incidence of induction characteristics. It is recommended that clinical studies of intravenous agents be limited to patients of physical status 1 and 2, if statistical tests are to be applied to the findings.

Muscle relaxants.

Table XII shows the significance levels of the difference in incidence of grade 1 inductions in otherwise comparable cases who were, or were not, given a long acting muscle relaxant prior to the injection of the thiobarbiturate. It is obvious that this use of relaxants markedly reduces the incidence of side effects of the anaesthetic (table VI) and the two groups of patients cannot be justifiably pooled for the purpose of analysis. In this study it was found that little information could be obtained from patients who were also given a long acting muscle relaxants and their only use seems to be the detection of interactions between the two types of drugs.

Dosage.

While too much attention should not be given to the average induction dose used for a variety of operations, this was consistently higher for males than for females (table VII). In only one group did this difference become statistically significant (table XIII). However, opiate premedication significantly reduced the induction dose of thiopentone (table XIV) in both males and females.

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BOOK REVIEW

Acta de l'Institut d'Anesthésiologie, Tome VIII. Cours Superieur d'Anesthésiologie, 1959. Publié sous la direction des Professeurs P. Moulonguet et J. Baumann. Librairie Arnette, Paris. Pp. 280; illustrated. Price 28 new francs.

The *acta* of the Institute of Anaesthesiology embody the views of the most competent specialists on present problems in the domain of the basic sciences, anaesthesia and resuscitation.

There are two studies on the physiology of the reticular substance. The one by Prof. Hugelin discusses the question as to whether there is or is not a "Centre of Sleep". Prof. Levy finds that "Aucune conclusion définitive ne peut être proposée actuellement", with respect to the physiological role played by normally synthesized serotonin. There are three articles that more immediately concern the anaesthetist: one by M. Leroy on the deadspace; one by G. Vourc'h on muscle relaxants, their mode of action and their antidotes; and one by J. Boureau on anaesthesia for the ambulant patient. All the other papers are so closely related to the practice of anaesthesia or concerned with the basic science on which it depends that a perusal of them cannot fail to improve the practice and widen the horizon of the thoughtful anaesthetist. Here is a list of them:

Intentional cardiac arrest and artificial stimulation of the heart.
Treatment of barbituric coma.
Intoxication associated with the metabolism of ammonia and hepatic coma.
The treatment of tetanus.
The re-animation of the head injured case.
Recent ideas in the domain of diuretics.
Resistance of anaesthetic apparatus.

It is evident that Tome VIII has much of interest for doctors, surgeons, anaesthetists, physiologists, and pharmacologists.

E. Falkner Hill

Brit. J. Anaesth. (1960), **32**, 219

SORE THROAT AFTER ANAESTHESIA

BY

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A sore throat is one of the more common sequelae of anaesthesia. Its relationship to endotracheal intubation and some of its more serious causes have been discussed by Wolfson (1958) who, in an analysis of 521 cases, found that the sex of the patient was the only factor affecting the incidence. By means of laryngoscopy at the end of anaesthesia Wylie (1950) noted the incidence of trauma produced by intubation.

This paper reports a study of the incidence of sore throat after anaesthesia and analyzes some of the factors which may have been responsible.

METHODS

All members of the Department co-operated in keeping punch-card records of all inpatients anaesthetized during the period from September 1958 to February 1959. On these cards were recorded the various details of the anaesthetic techniques employed. The techniques were those usually practised by the various anaesthetists taking part in the investigation; they were not influenced by the fact that an investigation was taking place. Some intubations were performed by students under supervision.

The details noted on the punch-cards included:

The operation performed;
Whether or not the patient was intubated;
Whether or not a Ryle's tube was passed;
Which, if any, muscle relaxant was used;
The method of intubation;
The type of laryngoscope;
The type of endotracheal tube;
The duration of intubation;
Any local anaesthetic spray solution;
The lubricant used on the tube;
Whether or not a throat pack was used;
Whether or not the intubation was considered difficult.

For three days after the anaesthetic each patient was visited in the ward by one of us (F.L.H.S.) who was not concerned with the actual administration of the anaesthetics and who recorded any symptoms on the same punch-card. A patient was considered to have a sore throat if he complained of this either spontaneously or upon enquiry. Loss of voice, hoarseness and stridor were assessed objectively. No patient's throat was examined, and no attempt was made to investigate the pathology of a sore throat.

For the presentation and the analysis of results, sore throats were classified as "mild" or "severe". A mild sore throat was arbitrarily defined as one which lasted for one or two days only, unaccompanied by loss of voice or hoarseness or stridor. A severe sore throat was defined as one which was accompanied by loss of voice or hoarseness or stridor, or one which lasted for three days or more.

RESULTS

One thousand four hundred and eight patients were observed but before analyzing the results all patients having undergone pharyngeal or laryngeal operations or peroral endoscopies were excluded.* The remaining 1,259 patients included 475 males and 784 females, of whom 130 (27.5 per cent) and 178 (22.5 per cent) respectively complained of sore throats (table I). This difference is not statistically significant.

Six hundred and seventeen of the series were not intubated, whereas 642 had endotracheal tubes passed. Postanaesthetic sore throat was nearly four times as common in the intubated cases as in those which were not intubated (table II).

Patients not intubated.

Of these 617 cases, 63 (10.21 per cent) had postanaesthetic sore throat; 54 (8.75 per cent) were classified as mild, and 9 (1.46 per cent) were classified as severe (table III). The available data do not suggest a possible cause of sore throat

* Of these 149 patients, 132 complained of sore throats. There was nothing remarkable about the 17 without symptoms.

TABLE I

The sex incidence of postanaesthetic sore throat.

	Symptom free	Mild sore throat	Severe sore throat	Total	P
Male	345 (72.5%)	67 (14%)	63 (13.5%)	475	>0.05
Female	606 (77.5%)	122 (15.5%)	56 (7%)	784	
Totals	951	189	119	1259	

$\chi^2 = 3.4824$.

TABLE II

Postanaesthetic sore throat and endotracheal intubation.

	Symptom free	Mild sore throat	Severe sore throat	Total	P
Not intubated	554 (90%)	54 (9%)	9 (1%)	617	<0.01
Intubated	397 (62%)	135 (21%)	110 (17%)	642	

$\chi^2 = 133.0144$.

TABLE III

Postanaesthetic sore throat in patients not intubated.

Relaxant used	Symptom free	Mild sore throat	Severe sore throat	Total	P
Total	166 (92%)	12 (7%)	2 (1%)	180	>0.3
d-Tubocurarine	14 (100%)	0 (0%)	0 (0%)	14	>0.2
Gallamine	127 (92.5%)	8 (6%)	2 (1.5%)	137	>0.2
Suxamethonium	24 (83%)	5 (17%)	0 (0%)	29	>0.2
No relaxant	389 (89%)	41 (9.5%)	7 (1.5%)	437	>0.3
Total	554 (90%)	54 (9%)	9 (1%)	617	

In this and the following tables the P values refer to the difference between the figures to which they are appended and the figures for intubated or not-intubated cases shown in table II.

TABLE IV

Type of laryngoscope and method of intubation.

	Symptom free	Mild sore throat	Severe sore throat	Total	P
Magill layrngoscope	6 (60%)	1 (10%)	3 (30%)	10	>0.9
Macintosh laryngoscope	369 (61%)	133 (22%)	101 (17%)	603	>0.7
Blind intubation	15 (52%)	14 (48%)	0 (0%)	29	>0.2
Direct vision	380 (62%)	122 (20%)	111 (18%)	613	>0.7

TABLE V

Postanaesthetic sore throat and type of tube used.

	Symptom free	Mild sore throat	Severe sore throat	Total	P
Cuffed tube	331 (64%)	103 (20%)	87 (16%)	521	>0.5
Noncuffed tube	37 (50%)	28 (38%)	9 (12%)	74	=0.05
Latex tube	29 (62%)	4 (8%)	14 (30%)	47	>0.9

in this group. It is possible that it was due to a multiplicity of causes such as the use of airways, premedication with drugs that diminish secretions, the use of mildly irritating anaesthetic agents and the unduly prolonged withholding of postanaesthetic drinks. One hundred and eighty patients in this group (32.5 per cent) received muscle relaxants but there was no increase in the incidence of sore throat in these compared with the group as a whole. It is possibly a chance finding that of 14 patients who received d-tubocurarine none developed sore throat ($P>0.2$).

Intubated patients.

Of the 642 patients who were intubated 245 (38.2 per cent) had sore throats, 135 (21.06 per cent) being mild and 110 (17.14 per cent) being severe (table II). With a few exceptions the incidence of sore throat was uniform among the intubated patients regardless of the techniques used or the agents employed. The exceptions and some of the cases conforming to this statement are worthy of further comment.

It was found that there was no greater incidence of sore throat following the use of a Magill laryngoscope than when a Macintosh laryngoscope was used (table IV). This is unlikely to be due to the small number of cases in which the Magill laryngoscope was used. Further work has been planned to separate the effects of laryngoscopy alone from those due to the presence of an endotracheal tube or to another cause.

The high incidence of sore throat when noncuffed tubes were used was an unexpected finding (table V). A possible explanation for this is that the inflated cuff anchors the tube in the trachea, so that movement of the tube relative to the trachea is unlikely to occur. Noncuffed tubes may move freely in the trachea, the larynx and the pharynx in response to movement of the patient's head or to respiratory movement.

Latex tubes, which were cuffed and armoured, were associated with the same incidence of sore throat as were ordinary rubber tubes.

Contrary to what might be assumed, no correlation could be found between the incidence of sore throat and the duration of intubation (table VI).

The insertion of a gauze pharyngeal pack moistened with water was associated with a high incidence of sore throat (table VII).

Red rubber Ryle's tubes which were swallowed in the ward by the patient before anaesthesia were associated with a high incidence of sore throat (table VIII).

TABLE VI

Postanaesthetic sore throat and duration of intubation.

	Symptom free	Mild sore throat	Severe sore throat	Total	P
Less than ½ hour	61 (54%)	28 (25%)	23 (21%)	112	>0.1
½ to 1 hour	192 (65%)	61 (21%)	44 (14%)	297	>0.5
1 to 2 hours	113 (60%)	40 (22%)	32 (18%)	185	>0.8
Over 2 hours	31 (65%)	6 (13%)	11 (23%)	48	>0.7

TABLE VII

Postanaesthetic sore throat and throat packs.

	Symptom free	Mild sore throat	Severe sore throat	Total	P
Wet throat pack	22 (39%)	24 (42%)	11 (19%)	57	<0.001

TABLE VIII

Postanaesthetic sore throat and Ryle's tubes.

	Symptom free	Mild sore throat	Severe sore throat	Total	P
Ryle's tube	47 (46%)	27 (27%)	27 (27%)	101	<0.001

Spraying of the larynx with local analgesic solutions had no apparent effect on the incidence of sore throat (table IX).

TABLE IX

Postanaesthetic sore throat and local analgesic sprays.

	Symptom free	Mild sore throat	Severe sore throat	Total	P
Total	93 (56%)	35 (21%)	37 (23%)	165	>0.2
Lignocaine 4%	92 (56%)	34 (21%)	37 (23%)	163	>0.1
Cocaine 10%	1 (50%)	1 (50%)	0 (0%)	2	>0.7

The use of local analgesic or other lubricants on the tube did not alter the incidence of sore throat except in the case of cinchocaine ointment, which was associated with a high incidence of sore throat (table X). This may be due partly to the greasy base of the preparation used, which might dissolve some irritant substance from the rubber of the endotracheal tube. The amethocaine ointment used had a similar base, but it was only used in six cases.

TABLE X

Postanaesthetic sore throat and lubricants used on tubes.

	Symptom free	Mild sore throat	Severe sore throat	Total	P
Lignocaine	271 (67.5%)	87 (21.5%)	44 (11%)	402	>0.05
K.Y. Jelly	128 (61%)	44 (21%)	38 (18%)	210	>0.8
Amethocaine	4 (67%)	2 (33%)	0 (0%)	6	>0.8
Cinchocaine	4 (27%)	6 (40%)	5 (33%)	15	<0.01
None	6 (67%)	3 (33%)	0 (0%)	9	>0.7

Of the muscle relaxants used, no statistically significant difference could be shown between the incidence of sore throat after suxamethonium and that after gallamine triethiodide or d-tubocurarine. There was, however, a trend toward a greater frequency of sore throat after suxamethonium and a lesser frequency after gallamine (table XI). Suxamethonium and gallamine, whilst not differing significantly from the mean incidence of sore throat, did show a significant difference from each other ($\chi^2 = 10.02$; $P < 0.05$). A possible explanation for this is that the relaxation provided by gallamine, unlike suxamethonium, does not wear off rapidly and thus does not expose a lightly anaesthetized patient to the risk of "bucking" on an endotracheal tube. The increased incidence of sore throat after suxamethonium may be part of the muscle-pain syndrome so often seen after the use of this drug. Gallamine might be expected to provide slightly better intubating conditions than d-tubocurarine, as its onset of action is more rapid.

Among the commoner causes of difficulty of intubation are a bull neck, prominent incisor teeth, a stiff neck, and laryngeal and masseter spasm. These factors were not associated with an increased incidence of sore throat (table XII). However a miscellaneous group of 15 patients in which intubation was recorded as "difficult", due to causes other than those mentioned above, showed a higher incidence of sore throat than

TABLE XI

Postanaesthetic sore throat and muscle relaxants with intubation.

	Symptom free	Mild sore throat	Severe sore throat	Total	P
d-Tubocurarine	42 (62%)	11 (16%)	15 (22%)	68	>0.8
Gallamine	130 (71%)	28 (15%)	26 (14%)	184	<0.05
Suxamethonium	133 (55%)	61 (25%)	46 (20%)	240	>0.05
Suxamethonium + another	89 (61%)	33 (23%)	23 (16%)	145	>0.9
No relaxant	3 (60%)	2 (40%)	0 (0%)	5	>0.9

TABLE XII

Postanaesthetic sore throat and difficult intubation.

	Symptom free	Mild sore throat	Severe sore throat	Total	P
Total	29 (51%)	14 (24.5%)	14 (24.5%)	57	>0.1
Bull neck	7 (50%)	2 (14%)	5 (36%)	14	>0.3
Prominent teeth	11 (69%)	3 (19%)	2 (12%)	16	>0.5
Stiff neck	1 (100%)	0 (0%)	0 (0 %)	1	>0.3
Spasm	6 (55%)	3 (27%)	2 (18%)	11	>0.5
Other causes	4 (27.5%)	4 (27.5%)	7 (45%)	15	<0.01

other intubated patients; 11 cases complained (72.5 per cent). In this miscellaneous group the 4 symptom-free patients were all those in whom too large a tube was first chosen and then abandoned in favour of a smaller one. Of the 11 patients complaining of sore throat, 4 were difficult nasal intubations, 2 had displacement of the trachea due to thyroid disease, 1 was a difficult endobronchial intubation, 1 had a small larynx, 1 was found difficult by a student, and in 2 cases no reason was stated.

Among the factors not investigated which might have caused postanaesthetic sore throat was the skill of the anaesthetist, which does not lend itself to measurement. The influence of inhalation anaesthetics was not investigated because to state, for example, that a patient was given halothane might mean that he was fully anaesthetized for a haemorrhoidectomy or that he was given a small amount because of sweating during a gastrectomy, when the main agent used was nitrous oxide. Likewise the effect of oropharyngeal airways on the incidence of sore throat was not studied because all patients who would tolerate them were returned to the ward with airways in place. In some patients they were used throughout operation whereas in others the airway merely replaced an endotracheal tube at the end of it.

Again, it was hoped to investigate the influence of the size of endotracheal tube but the difficulty of measuring the other variable, the size of larynx, made this pointless.

The method of sterilizing the endotracheal tube might influence the incidence of sore throat, but all tubes used were sterilized by boiling just after the end of the previous operation in which they were used.

SUMMARY

The incidence of postanaesthetic sore throat in 1,259 patients undergoing general anaesthesia was 308 (24.5 per cent).

In 617 patients who were not intubated the incidence of sore throat was 63 (10.2 per cent).

Of 642 patients who were intubated 245 (38.2 per cent) developed sore throat.

The influence of some of the factors that might have been responsible for this complication of anaesthesia is discussed.

ACKNOWLEDGMENTS

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THE RADIATION HAZARD TO ANAESTHETISTS*

BY

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NUMEROUS diagnostic radiological procedures are carried out on anaesthetized patients. These may be purely of a diagnostic nature, such as angiography, bronchography or cardiac catheterization, in which case the anaesthetic makes the radiological technique tolerable to the patient. Diagnostic radiology may be performed during surgical operations, as, for example, fixation of femoral neck fractures and cholangiography in biliary tract explorations. In either case an anaesthetist is present, and in the latter theatre staff are grouped round the operation.

No investigation has been traced concerning the amount of exposure to X-rays which anaesthetists and theatre staff receive; although radiation dosage received by diagnostic X-ray workers has been measured by Osborn (1955) and Ardran et al. (1957). Their conclusions are not comparable with the present investigation, since the amount of exposure and conditions of work of radiologists and radiographers are very different from those of anaesthetists. It was in order to establish the radiation levels to which anaesthetists and theatre staff are exposed that the present investigation was undertaken. The first part will deal with some properties of X-rays. The investigation will next be described, and finally an attempt will be made to interpret the results in the light of present-day opinions.

PROPERTIES OF X-RAYS

X-rays are one form of electromagnetic waves. The wavelengths range between the 1000 metres or more of radio waves to the 0.01 X units (X unit = 10–11 cm) of cosmic rays. Basically, all these waves consist of a cyclic variation of an electric field and are propagated through space at the speed of light, namely 186,000 miles per second. The various types of electromagnetic waves are formed in different ways. Thus, radio waves are produced by the oscillation of electric charges backwards and forwards along a conductor known as the aerial and are detected when, in the receiving aerial, they produce small oscillating potentials which are in turn amplified by the sensitive circuits of the receiver. Infrared rays and light waves are produced by heat and are received as such when the heat is absorbed. On the other hand, X-rays are formed when a stream of electrons impinges on certain metals. On their absorption, electrons are displaced from atoms and this results in ionization and chemical change. All electromagnetic waves represent a form of energy transfer. The exact effects in a receptor vary with the wave lengths, but the basic physical behaviour of the waves is the same.

The ionization in living tissues caused by X-rays of absorption causes the biological effects which concern this investigation. X-rays cause multiple ionizations, as the electrons initially displaced travel through the material causing further displacements. The process of ionization involves physico-chemical changes in the molecules affected which, in turn, alter the function and behaviour of the cell. The precise effect varies with the intracellular site of impact and with the type of cell. A somatic cell may be so damaged as to die, or it may be induced to uncontrolled multiplication and invasion. A gonadal cell may carry the effect into a future generation if the chromosome or gene is altered.

As well as sharing the property of energy-transfer with other electromagnetic waves, X-rays show similar behaviour in other respects. Three relevant properties are (*a*) rectilinear propagation, (*b*) scatter, and (*c*) the inverse square law of intensity. As with light waves, X-rays, for our purposes, travel in straight lines. Scatter is a more complicated problem of higher theoretical physics, but it is sufficient to say that X-rays can be scattered in various directions from matter on which they impinge. The inverse square law states

* This paper is modified from the essay which was awarded the 1959 Annual Registrar's Prize of the Sheffield and East Midlands Society of Anaesthetists.

that the intensity of the radiation received varies inversely as the square of the distance from the source. Thus, if the distance between source and receptor is doubled, the received intensity is reduced to a quarter; if it is trebled it becomes a ninth. Increasing distance from the source of radiation is therefore of considerable importance when protection and measurement of dose is discussed.

The measurement of X-ray dosage is carried out by utilizing the effects that result from the energy release from ray absorption. A crude method in early days was the erythema method in which a unit of dose was defined as the amount of radiation which just produced a reddening of the skin. There are many fallacies in this method and the doses so measured are, by modern standards, very large. The "Pastille Dose" utilized the energy of X-rays to turn barium platino-cyanide from yellow to brown. This method is also very inaccurate because of variability in the appreciation of and estimation of changes in colour. The blackening of ordinary photographic film gives a fairly reliable indication of the exposure to X-rays, though shielding of part of the film to eliminate undesirable frequencies is essential. This is the commonly used routine method for radiological staff and persons working with radioactive materials. After development, the relative blackening of the film is measured by the amount of light transmitted to a photocell. The instrument most suitable for measuring fairly accurately very small doses is the B.D.11 chamber condenser (fig. 1). It consists of a central electrode (E) inside the chamber (W). Both are made of a bakelite-graphite mixture. The electrode is mounted on an insulator (I) and is accessible by the screw-cap (C). When the electrode is charged, the air in the chamber prevents dissipation of the charge. The passage of X-rays through the chamber causes ionization of the air and enables it to conduct the charge from the electrode to the chamber. After exposure the electrode is connected to an electrometer and the remaining charge measured. The dissipation of the charge is proportional to the amount of exposure. This instrument was used in the current investigation.

It must be emphasized that this present investigation refers only to diagnostic X-rays and these are not the only form of ionizing radiation to which anaesthetists may be exposed. Those associated with radiotherapy units have also to contend with the emissions from radioactive materials. These are alpha and beta rays and to a small extent neutrons. They are particulate, unlike X-rays, and have different physical properties although they can produce, under certain circumstances, similar and especially harmful effects. Gamma rays, similar to X-rays, are also emitted from radioactive materials used in therapy, such as radium and cobalt 60.

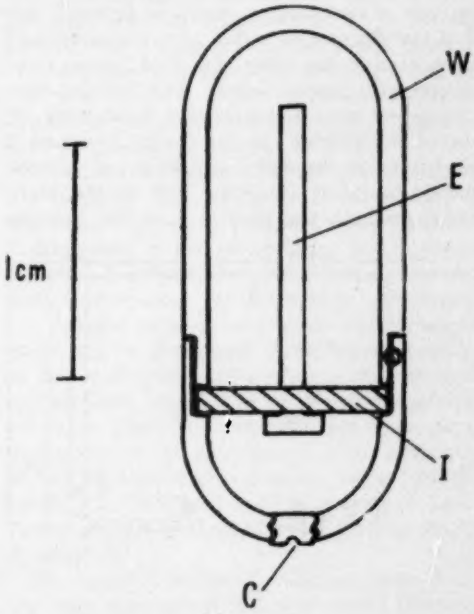

FIG. 1

THE INVESTIGATION AND METHOD

Exposure to ionizing radiation was measured by the discharge chambers (B.D.11) previously mentioned. They were used in pairs placed in a canvas bag. This duplication was in order to avoid errors due to accidental discharge of a chamber, this being a possible hazard of these instruments. The chambers thus acted as controls of each other.

Calibration of the chambers was carried out to determine the amount of discharge produced

by unit amount of radiation. The range of X-rays employed in diagnostic work, namely those produced by 60 to 120 kv, was used in the calibration, since the amount of discharge depends on the energy of the X-rays. Therapeutic radiology, for instance, with higher energy X-rays is carried out above the 200 kv range. The unit of radiation into which measurements were converted is the millirad (m/rad) — a thousandth of a rad. One rad is that amount of radiation which releases one hundred ergs of energy in one gram of the irradiated material.

With three exceptions, the chambers were exposed in the position shown in figures 2 and 3 in two theatres. One (fig. 2) is a general operating theatre; the other (fig. 3) a special room designed for neuroradiology. The positions were chosen as being representative in showing the spread of radiation. In the theatre, positions 1 to 4 were on the walls, at a height of approximately four feet. Position 5 was on the anaesthetic machine, and position 6 on the anaesthetist's stool. In the diagnostic room, the positions were similar, but due to the smaller size of the room the chambers were nearer to the X-ray apparatus. The three series of readings elsewhere were in the nature of a pilot study to ascertain whether significant variations occurred under other conditions. One was a bronchogram performed in a radiological department, one was a cardiac catheterization carried out in another department, and the third a series of cerebral angiograms in a third main department. The chambers in these three cases were placed in similar positions to those in the main series.

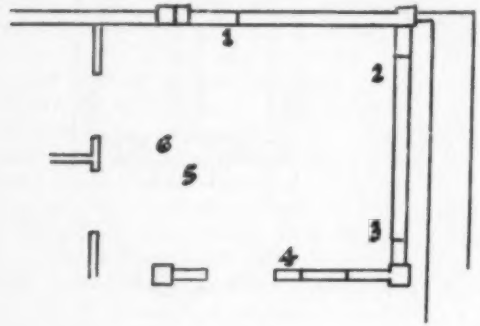

FIG. 2

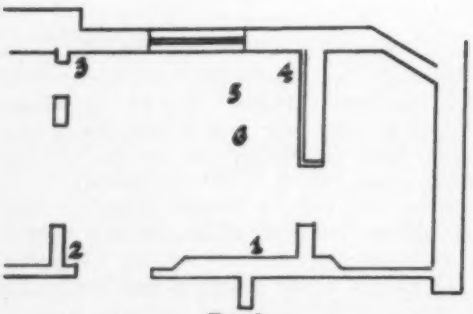

FIG. 3

RESULTS

Measurements were taken in 17 cases. Of these, seven were cerebral angiograms. Seven operations consisted of open fixations of femoral neck fractures. One operative cholangiogram, one bronchogram and one cardiac catheterization complete the series. Owing to the large number and complexity of the actual readings, the tables of results are not included. Instead, the results quoted represent a summary of the figures obtained. The results in the first four positions can be classified together since they represent the generalized spread of radiation and show the exposure of theatre staff and radiographers as well as the actual operators.

Positions 5 and 6 give the exposure to the anaesthetist's place at the patient's head. The first four positions are also relevant to the anaesthetist since he may not always be at the head of the table.

In positions 1 to 4, in the general theatre, the heaviest recorded dose was 60.3 m/rad. In this case more films were exposed than in any other in this theatre, though no similar readings were obtained in other cases with slightly fewer films. This one result is difficult to interpret, but owing to the accuracy of the method it must be assumed that the readings are true. It is unlikely that accidental partial discharge of both chambers to the same degree occurred. In general, the readings in positions 1 and 4 were higher than in 2 and 3. This may be due to their greater proximity to the X-ray apparatus. The highest reading apart from the above was 10.8 m/rad in position 1 in one case and 7.4 m/rad in position 4 in another.

Positions 5 and 6, representing the anaesthetist, showed similar readings in the general theatre series. The highest in position 5 was 6.9 m/rad; and in position 6 the greatest reading was also 6.9 m/rad.

The measured radiation during cerebral angiography was, in general, greater. This may be attributed to the smaller size of the theatre and to the greater numbers of radiographs taken in each session. Also, when air encephalography was undertaken, the position of the X-ray tube was favourable for spread of radiation. As in the general theatre, positions 1 and 4 tended to show greater exposures, again probably due to the proximity to the X-ray tube. The maximum recorded in position 1 was 15 m/rad. Fourteen m/rad were registered in position 4. In the anaesthetist's position, higher doses were received than in the general theatre, probably for the same reasons. In position 5 the highest was 10 m/rad and in position 6, 21 m/rad.

Readings in the three pilot studies were, with one exception, within the same range as those noted in the general investigation. The exception was position 2 in one case where 29 m/rad were recorded. It was assumed that the equivalence of the doses received in the pilot studies to those in the general investigation was significant and that it showed a similarity of conditions.

The maximum doses received in the investigation were deemed to be more important than the means (which were not calculated) because it was considered more important to record the greatest doses to which staff were exposed.

Summarizing, the measured radiation per session was, with one exception, in the range of 5 to 30 m/rad. The variation is relatively great, but in terms of doses known to cause immediate effects the amount of radiation is small.

DISCUSSION

The harmful effects of radiation have been known for over sixty years. Soon after Becquerel's discovery of radioactivity and Roentgen's early work with X-rays at the end of the nineteenth century, other investigators were found to suffer from certain types of lesions. The hazards were soon realized and described by Desjardins in 1923, when the first recommendations in regard to protection were made.

The dangers to man of radiation are twofold: somatic, representing damage to the individual and affecting him adversely during his lifetime; and genetic, being the effects seen in later generations due to damage to gonadal cells. All forms of radiation, particulate and electromagnetic, cause such damage by the same mechanism. The ionization produced in the atoms of the living cell alters the cell in some respect. The change may take the form of disorganization of a metabolic process, such as an enzyme cycle, and may thus cause the cell to proliferate or to die. In gonadal cells a similar mechanism may operate, causing death or malignancy. A change may be produced, however, in the chromosomal characteristics of the cell which would only manifest itself in a future generation.

In considering the somatic effects of radiation, two concepts must be borne in mind. One is that a given amount of radiation may be harmful if distributed to the whole body, but relatively harmless if concentrated on a small area. An example of this is in the treatment of epithelioma. The doses of radiation used on the tumour might prove fatal if distributed throughout the body. In this investigation all exposures are regarded as whole-body doses, since no protective clothing was worn. The other concept is that of the time distribution of the radiation. A given dose may be fatal if received at one instant but apparently harmless if distributed over an interval of time. These concepts also apply to the genetic effects of radiation.

The harmful results of radiation have been very fully documented and summarized (Report, 1958). These include leukaemia, aplastic anaemia, dermatitis, alopecia, keratitis and skin tumours. When known, the doses of radiation causing damage have been very high—200 rad whole body dose or more. Recent figures concerned with morbidity in persons exposed to radiation have been suggestive but inconclusive. Court Brown and Abbott (1955) showed an increase in the expected increase in leukaemia in patients treated by radiation for ankylosing spondylitis. A heavy increase in leukaemia incidence was noted in the survivors of Nagasaki and Hiroshima (Folley et al., 1952). A large number of reports showing

malignant changes following irradiation for thyroid and thymic tumours are available. The possible dangers of radiology during pregnancy have also been described.

The genetic effects in man are, of course, difficult to assess as not enough time has elapsed since radiology became widespread. Actual mutations have been produced in animals and insects by large doses, the effects being seen in the first generation. Whether these are applicable to human beings is undecided. Statistically, only studies of large populations can show the degree of damage in future generations.

The present-day maximum permissible dose for persons working with ionizing radiation is 300 m/rad whole-body exposure per week. It should be noted here that this dose is only one hundredth of that acceptable 30 years ago. Present-day protection standards (H.M.S.O., 1957) relate to the assumption that such dosage is harmless. In view of the progressive reduction of acceptable dosage in the last 30 years, this may be regarded as open to question.

The doses noted in this investigation are, on the present-day standard, well within the safety limits. Nevertheless some radiologists (Ardran et al., 1957) have kept exposures in their departments to very much lower levels, such as 5 m/rad per week. It would seem that under ideal protection arrangements such doses are much to be preferred. As already noted, known harmful effects result from very much higher doses. The possible results of small dosages are described by Lamerton (1958). He states that a threshold, below which radiation is completely harmless, probably does not exist. If this is true mutations will occur, however small the dose. Mutations are always harmful when produced in this way, though their effects may not be seen for a very long time. It is felt, therefore, that in order to avoid another agonizing reappraisal, dosage must be kept to the absolute minimum or, where possible, abolished altogether. Recently it has been shown (*Lancet*, 1959) that even small doses of radiation are more harmful if distributed as short, sharp bursts rather than in a more gradual fashion such as background radiation. This adds emphasis to the need for reducing radiation, especially when large doses are given intermittently as during diagnostic radiology.

The practical ways of minimizing exposure are numerous. The use of modern completely protective equipment by fully trained personnel is essential. Periodic checks of machines and equipment by physicists and preferably continuous monitoring should be the general practice. Protective clothing, such as lead aprons and gloves, must be available and used always. An awareness of the dangers in all persons working with radiation is very helpful in minimizing the effects.

The results of this investigation are relevant only to the particular places and conditions under which it was carried out. The pilot studies show a sufficient similarity to indicate that the results are fairly typical. Readings have not been taken in other situations where anaesthetists might be exposed. Whole-body doses only have been measured, whereas localized exposure, for instance to the hands, might have shown greater doses. Therapeutic radiology and radium give rise to radiations which could not be measured with the apparatus in the investigation. The use of radioactive isotopes also gives rise to a radiation hazard. The author recently had occasion to anaesthetize a patient who had two days previously received a therapeutic dose of radioactive iodine which was concentrated in the thyroid. A further investigation is planned to discover the possible hazard under such conditions.

To summarize, the doses received under the circumstances of this study were very small and possibly harmless. Nevertheless it is safer to take the view that "no radiation is safer than any radiation" and have no regrets, especially when convenient and simple methods for protection are readily available.

SUMMARY

The physical properties of X-rays are described where they are relevant to the study. A series of readings of radiation exposure was taken in positions where anaesthetists and theatre staff might be during diagnostic radiology. The results were well below present-day permissible standards. The dangers of small doses of radiation and protective measures are discussed.

ACKNOWLEDGMENTS

I wish to acknowledge the help of all colleagues who participated in the investigation, in particular Dr.

J. A. Griffiths. The radiation measurements were undertaken by the Department of Physics, Sheffield National Centre for Radiotherapy, to whose staff I owe much gratitude. The diagrams are by Mr. Foster, medical artist to the Sheffield Royal Infirmary.

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BOOK REVIEW

Surgical Technique (2nd edition). By Stephen Power. Published by Heinemann Ltd., London (1959). Pp. 403; illustrated. Price 40s.

It is eight years since the first edition of this excellent little book was produced, but I anticipate that eight years won't pass before a third edition is called for. As the author remarks in his preface, a section on catheter drainage has been added to the chapter on drains; the chapter on wound surgery has been amended; the chapter on shock has been renamed "Transfusion and Infusion" and a chapter has been added on instruments. As a guide for a surgical assistant and a most pleasing piece of reading for any doctor the book can be recommended with enthusiasm. "Never a dull moment" would be a fitting motto for *Surgical Technique*. It is well written and the short snappy sentences maintain the reader's interest.

Rarely does one fail to learn something new when reading any medical textbook and certainly there are many points to be picked up from this worthwhile product. All house surgeons should have it readily to hand and for others on the surgical "fringe", there is much useful information. It is nice to learn that a new use has been found for a Murphy's button!

Certainly the book may be on the expensive side, but it is well illustrated and may possibly be thought well worth £2 after it has been read.

There is little to criticize in *Surgical Technique* —shouldn't Hartman be Hartmann?—and much to praise.

No reader of the *British Journal of Anaesthesia* will fail to pick up some "tip" or think a reading hasn't been worth while. For any candidate for the higher examinations in anaesthesia there is much to be learnt which will help him to defeat the hostile examiner and at the same time help him in the practice of his specialty.

A. Hedley Whyte

Brit. J. Anaesth. (1960), **32**, 230

A RIGHT-SIDED DOUBLE LUMEN TUBE

BY

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LEFT rather than right endobronchial intubation has always been preferred because of the greater distance between the carina and the division of the bronchus on the left side. This presents difficulty in the case of blind intubation, for even with a properly shaped tube, it is not always possible to enter the left bronchus with certainty. On the other hand, as anaesthetists well know, inadvertent intubation of the right side is often distressingly simple. Unfortunately it is not possible to make use of this easy manoeuvre with a normal Magill tube in endobronchial anaesthesia, since the likelihood of obstructing the right upper lobe bronchus is high. However, the introduction of a "slotted" cuff near the distal end of a tube (Green and Gordon, 1957) has overcome this problem and the high proportion of successes in siting of the Green-Gordon tube makes blind, right endobronchial intubation a practical possibility.

Nevertheless, the stability of essentially straight or unshaped tubes cannot be guaranteed, even though accurate placing with a bronchoscope has been possible. The oropharyngeal curve found in the Carlens (Carlens, 1949) or M-L (Macintosh and Leatherdale, 1955) tubes appears to reduce considerably the chances of displacement and, in this respect is more important than cuffs, spurs or other modifications of the tube. Our intention, therefore, has been to combine the merits of several tubes in one, which, having been introduced easily into the right main bronchus without interfering with the airway to the upper lobe, would not be displaced. Further, this tube should be a double lumen catheter for independent control and protection of the lungs. It was first thought that this would be a logical modification of the Carlens catheter to be used when intubation of the left main bronchus was impossible by virtue of local pathology or the nature of the surgery envisaged. However, the ease with which the tube to be described can be inserted, leads one to suggest that right-sided intubation could well become the rule, with left intubation as an occasional alternative rather than the reverse.

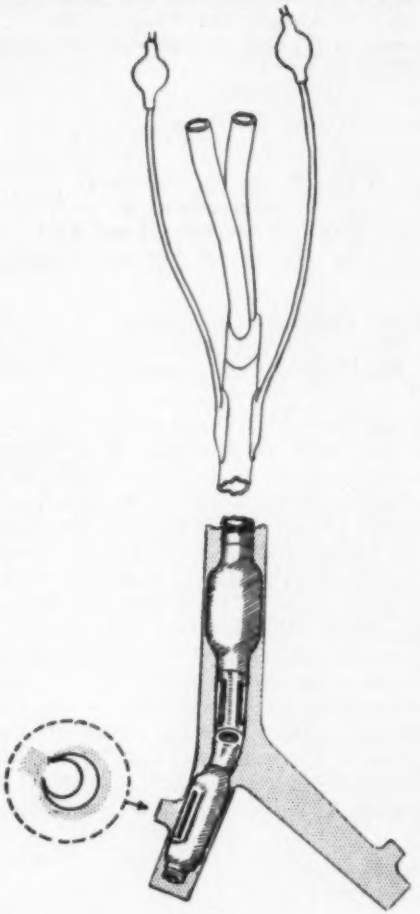

FIG. 1

Right-sided double lumen tube in position. Inset shows a section (enlarged ×2) of the slotted cuff in relation to the upper lobe orifice.

DESCRIPTION

This tube may be regarded as a right-sided version of the Carlens catheter. The method of construction is similar to that of the double lumen tube already described (Bryce-Smith, 1959). The distal, endobronchial section is directed to the right at an angle of about 17° and carries an inflatable, slotted, cuff which faces anterolaterally. The slot measures 15 × 4 mm and is forced against the right upper lobe orifice on inflation of the cuff to establish a seal within the bronchus. A cuff on the double lumen section of the tube is inflated in the trachea.

The tube is inserted through the larynx with the aid of a laryngoscope and, as soon as the double lumen section has entered the trachea, the laryngoscope is removed. The tube is now advanced blindly with the pharyngeal curve of the tube in the anteroposterior plane. When in position, both cuffs are inflated and the correct siting of the tube confirmed by auscultation. To do this efficiently the patient should remain apnoeic and the individual limbs of the tube occluded in turn while intermittent positive pressure ventilation is carried out.

Where there is gross distortion of the trachea, preliminary bronchoscopy is advisable and, although not essential, it may be helpful in assessing those individual variations in the division of the bronchi which occur within the range of normality. As a general rule, however, no difficulty is encountered in making the tube enter the right main bronchus but adjustment may be necessary to ensure a clear airway to the upper lobe. The following points must be remembered:

(1) Over inflation of the bronchus cuff within the bronchus may lead to herniation over the slotted orifice. Careful inflation of this cuff is therefore important, even though this risk has been reduced by sealing the cuff at some distance from the slot in the tube. Herniation beyond the distal orifice of the tube is possible but is unlikely to occur.

(2) The tube may not have been passed far enough into the main stem bronchus. The upper lobe orifice will therefore be obstructed by the distal portion of the tube or cuff. This can be corrected by advancing the tube gently—an adjustment which might not be possible in tubes having a carinal spur.

(3) Alternatively, the obstruction may be caused by the proximal portion of the cuff, in which case a slight withdrawal of the tube is indicated.

During the experimental use of the tube, faults have been encountered most commonly in the above order. This sequence of investigation and correction should be carried out whenever the tube is not correctly placed when first introduced.

The proximal limbs of the tube are left long so that they may be cut to suit individual requirements. They may be connected to the anaesthetic apparatus by means of separate connectors joined by lengths of rubber tubing to a Y-piece or, more conveniently, by means of the White-Salt double lumen adaptor (White, 1959).

Dr. Malcolm White, of Middlesbrough, has also investigated the use of a right-sided double lumen tube (v. p. 232, this issue). His design closely follows that of the Carlens catheter and is made by Messrs. Rüsch of Stuttgart. We are grateful for the help and assistance given in the development of this tube by the Leyland and Birmingham Rubber Co., Preston, Lancs. The tubes are available in three sizes, 6, 6.5, and 7 (indicating the diameter of each tube in millimetres), from Messrs. M. & I.E. Ltd., 10/12 New Cavendish Street, London, W.1.

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A NEW DOUBLE LUMEN TUBE

BY

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THE value of the double lumen tube in anaesthesia for thoracic surgery has become more widely appreciated in recent years. Besides being more stable than single lumen endobronchial tubes and bronchial blockers, it permits differential pulmonary ventilation.

The best example of such a tube is the Carlens catheter (Bjork and Carlens, 1950) which was designed to intubate the left main bronchus. This can be used for operations on both lungs, but where it is necessary to amputate the left main bronchus close to the carina, the tube must first be partly withdrawn into the trachea. Difficulty in ventilation is often encountered after this manoeuvre, and is probably due to the orifice of the right tube being brought into apposition with the side wall of the trachea.

FIG. 1

FIG. 2

This difficulty has been overcome by a new double lumen tube (figs. 1, 2 and 3) designed for blind right endobronchial intubation. It is made from rubber, moulded to the shape of the right main bronchus, trachea and orotracheal airway. Each tube has a D-shaped section in the tracheal part, the left one terminating just above the carina, while the right one is continued as an endobronchial tube. A small rubber hook situated just below the orifice of the left tube, is designed to engage the carina to ensure correct

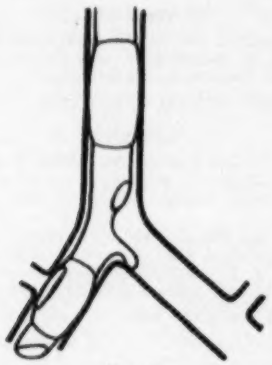

FIG. 3

positioning of the tube and to provide stability. Bronchial and tracheal inflatable cuffs are incorporated to provide an airtight and watertight seal with the trachea and bronchus. The conduit tubes to the cuffs are differentiated by their colour, red being for the bronchial cuff and white for the tracheal one. The bronchial cuff has a slit which communicates with the lumen of the tube, and when the tube is in position this slit is in apposition with the orifice of the right upper lobe bronchus, thus permitting ventilation of the right upper lobe. This cuff is a modification of the original one designed by Green and Gordon (Green and Gordon, 1955).

Before the tube is introduced, bronchoscopy is performed in order to confirm anatomical normality of the right main bronchus and orifice of the right upper lobe bronchus. With the aid of a laryngoscope, the endobronchial part of the tube is introduced into the glottis, and at this stage the oral part of the tube is pointing to the left of the patient, while the carinal hook is above the posterior part of the glottis. The tube is then rotated clockwise through little more than half a circle, i.e. about 200°, so that the carinal hook now lies in the anterior part of the glottis where its passage between the cords is permitted. The tube is then rotated anticlockwise through a quarter-circle, so that the endobronchial tube is now pointing to the right. This ensures intubation of the right main bronchus when the tube is advanced further and a definite end point is reached when the carinal hook engages the carina. Once in position, the tube is firmly secured with bandage or adhesive strapping. Before inflating the cuffs, a two-way union (Salt and White, 1959) is connected to the tube and the lungs ventilated. This union merely provides quick and easy control of the gas flow to each lung together with facilities for suction. The bronchial cuff is gently inflated until no escape can be heard when the right lung is ventilated. Similarly, the tracheal cuff is then inflated until no escape can be heard when the left lung is ventilated.

The position of the tube is now confirmed by auscultation over the lung fields, while controlled ventilation is carried out. Each lung field is auscultated with the corresponding tube first open then closed, and breath sounds on one side should be completely absent when the corresponding tube is closed and vice versa. Breath sounds heard over the right upper lobe area, with the right tube open, confirm correct apposition of the slit cuff with the orifice of the right upper lobe bronchus. These findings confirm that the tube is positioned satisfactorily.

Since the greater length of each tube has a D-shaped cross-section, the passage of a rubber suction catheter sometimes proves difficult, but a lubricated polythene catheter passes easily. The tube is made from mineralized rubber, and may be sterilized by boiling.

TABLE I

Flow resistances in millimetres water.

Litres/min	5	10	15	20	25
Double lumen tube, Size F.G. 39.					
Both tubes	0.8	2.3	4.2	6.6	9.4
Right tube	2.3	6.8	13.2	21.0	30.0
Left tube	2.1	6.1	11.2	17.0	25.0
Magill endotracheal tube, size no. 8, length 31 cm	—	5	7	10	15

Flow resistance measurements in millimetres water can be obtained from the accompanying table, and a comparison with those of a No. 8 Magill endotracheal tube can be made.

A trial with the prototype proved that satisfactory function of the tube was dependent on

confirmation by bronchoscopy, before intubation, of a normal anatomical relationship between the right main bronchus, right upper lobe bronchial orifice and carina. The present tube has been used in more than thirty patients undergoing thoracic surgery and function was satisfactory in every case.

The tube is manufactured by Willy Rusch of Stuttgart, and is made in three sizes, F.G. 37, 39, and 41. It is obtainable in this country from, Genito-Urinary Co., Ltd., London.

ACKNOWLEDGMENT

I am indebted to Dr. H. G. Epstein of the Nuffield Department of Anaesthetics, Oxford, for carrying out the flow rate resistance measurements.

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CORRESPONDENCE

THE FIRST ADMINISTRATION OF CHLOROFORM

Sir,—In his interesting article on "The Evolution of Anaesthesia" (*Brit. J. Anaesth.*, 1960, **32**, 141) Dr. Armstrong Davison repeats the story which until recently was believed to be true, that Simpson was the first person to administer chloroform for surgical anaesthesia at some date between November 4 and November 8, 1847.

I think that it must now be regarded as proved beyond reasonable doubt that Mr. Holmes Coote gave chloroform in the form of "chloric ether" (i.e. mixed with alcohol) to a patient of Mr. (later Sir William) Lawrence for a surgical operation at St. Bartholomew's Hospital in the *spring* of 1847 at the suggestion of Mr. M. C. Furnell, an Army surgeon.

The priority of London over Edinburgh (in this matter only, of course) was hinted at in Dr. Barbara Duncum's book *The Development of Inhalation Anaesthesia* published in 1947, but has now been investigated fully and confirmed by Dr. Stanley Sykes in his recently published *Essays on the first hundred years of Anaesthesia*, Vol. I, p. 164.

C. LANGTON HEWER
St. Bartholomew's Hospital,
*London, E.C.*1

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Brit. J. Anaesth. (1960), **32**, 235

EVOLUTION OF ENDOTRACHEAL AND ENDOBRONCHIAL INTUBATION

BY

G. M. J. WHITE

Poole Hospital, Middlesbrough, England

ENDOTRACHEAL intubation was probably first performed by the eminent Belgian anatomist, Andreas Vesalius in 1543 (Vesalius, 1543). After performing a preliminary tracheotomy on a pig, he inserted a tube of reed or cane into the trachea, opened the thorax and then applied artificial ventilation by blowing down the tube. This proved to be a most advanced and skilful manoeuvre, for it was not until centuries later that its value as a means of maintaining pulmonary ventilation after thoracotomy was fully appreciated.

The next two hundred years saw little further development in tracheal intubation, but by the end of that time, the need for more effective resuscitative measures was becoming increasingly obvious. Mouth-to-mouth breathing had been performed as a resuscitative technique since biblical times, and in the early part of the sixteenth century, Paracelsus, a physician and lecturer of Basle, reported the recovery of a case of asphyxia with a bellows connected to a tube placed in the mouth of the patient (Guthrie, 1945). It would appear that endotracheal intubation, as a means of resuscitation, was first performed in 1754, when Benjamin Pugh, a Chelmsford surgeon, designed an "air pipe" (fig. 1) made from a coiled wire covered with soft leather (Spencer, 1925). The "air pipe" was introduced orally into the trachea of an asphyxiated neonate by a tactile technique; the operator then blew down the tube intermittently. It proved to be an effective method, although introduction of the pipe was difficult and usually traumatic. Little further interest was shown in neonatal intubation during the next half-century, but in 1807 Chaussier, physician to the Maternité de Paris, produced a curved metal cannula (fig. 2) which could be introduced into the trachea blindly, and again the operator insufflated the lungs of the neonate by blowing down the cannula intermittently (Northrup, 1894). Similar cannulae were produced by Depaul (1845) in 1845 (fig. 3) and in 1858 by Ribemont (fig. 4), both obstet-

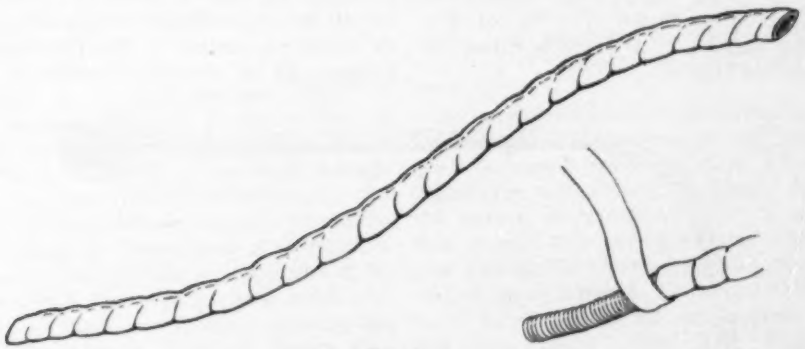

FIG. 1
Pugh's air pipe (1754).

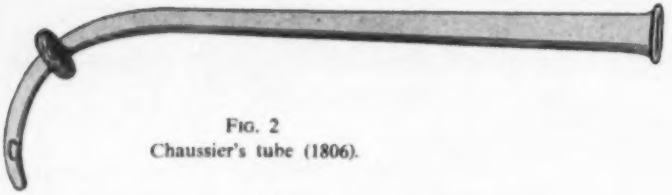

FIG. 2
Chaussier's tube (1806).

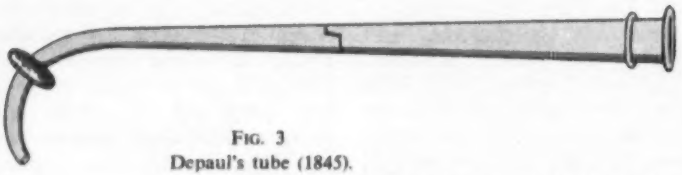

FIG. 3
Depaul's tube (1845).

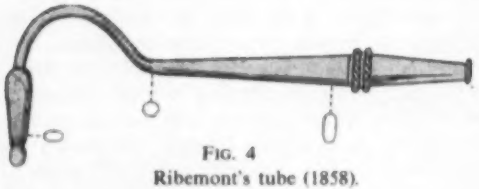

FIG. 4
Ribemont's tube (1858).

ricians at the Maternité de Paris. Ribemont's cannula had a conical tip to ensure an airtight seal with the larynx, while the cannulae of Chaussier and Depaul had sponge collars.

In the meantime Charles Kite, a surgeon of Gravesend, had encountered several cases of apparent drowning in the Thames, and in 1788 he reported having successfully resuscitated some of them by insufflation with the aid of a curved metal cannula (fig. 5) which he introduced into the trachea blindly.

During the first half of the nineteenth century, surgical procedures on the upper respiratory tract were performed more commonly and this led to a noticeable rise in the incidence of postoperative pneumonia. Attention was thus directed to the problem of preventing the aspiration of blood and debris during such operations. Freidrich Trendelenburg, while an assistant surgeon at Langenbeck's clinic in Berlin, showed interest in this problem and as a result he produced a tampon cannula which was merely a curved metal tracheotomy tube with a tampon collar (Trendelenburg, 1871). From this he developed the first inflatable cuff (fig. 6) which was a delicate double-walled indiarubber tube surrounding the tracheotomy tube. It was introduced in 1869 and although successful in that it prevented aspiration of foreign matter, it entailed tracheotomy, the need for which was obviated by later developments in laryngoscopy and orotracheal intubation.

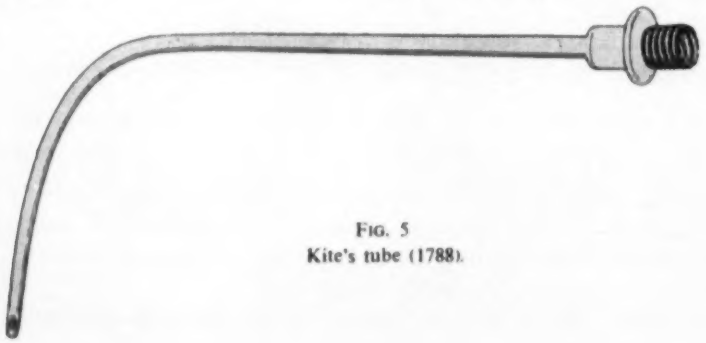

FIG. 5
Kite's tube (1788).

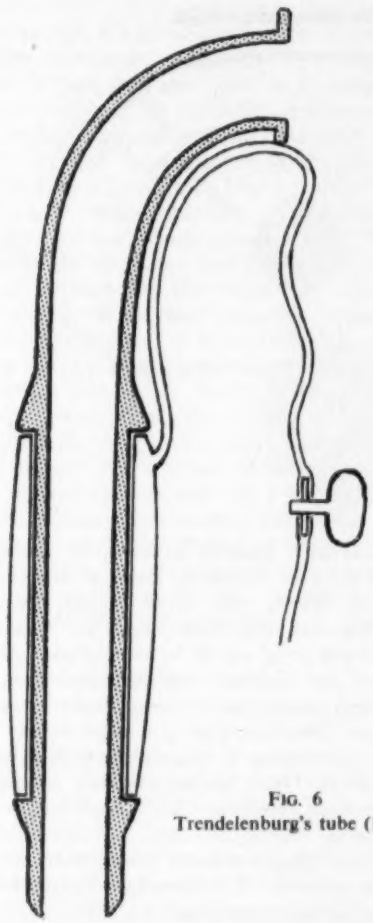

FIG. 6
Trendelenburg's tube (1871).

The work of William Macewen (1880), a Glasgow surgeon, occupies a prominent place in the history of endotracheal anaesthesia because he was the first to administer an anaesthetic through an orotracheal tube. Like Trendelenburg, he was primarily concerned with preventing aspiration, but, like others, he disapproved of Trendelenburg's tracheotomy. In 1880 he designed a metal endotracheal tube with a sponge collar which was introduced by touch, the sponge occupying the laryngopharynx. Maydl (1893) of Prague also advocated the use of a pharyngeal sponge to prevent aspiration, but Eisenmenger (1893) of Vienna was probably the first to use an inflatable cuff attached to an orotracheal tube (fig. 7).

The next problem which influenced the development of endotracheal anaesthesia was that of preventing pulmonary collapse after thoracotomy. O'Dwyer (1887), a New York otolaryngologist, had acquired fame through his introduction of metal laryngeal tubes (O'Dwyer, 1887; see also Kelly, 1928) in cases of diphtheritic croup. In 1888 he went on to design a curved metal cannula with a conical end (fig. 8) to ensure an airtight seal with the larynx (Northrup, 1894). This cannula, together with the foot bellows invented by Fell of Buffalo, was used to apply a raised intratracheal pressure, thus preventing pulmonary collapse during thoracic surgery.

Although Macewen had introduced orotracheal anaesthesia in 1880, it was Franz Kuhn, of Kassel in Germany, who popularized it (Fischer, 1933). The value of endotracheal intubation in preventing aspiration was now fully appreciated. At the turn of the century, however, Franz Kuhn became aware of the importance of intubation as a means of removing secretions from the tracheobronchial tree, as well as providing a good airway for smooth anaesthesia and it appears that he was the first to appreciate this. He designed a malleable endotracheal tube made from a wire spiral with a rubber insertion (fig. 9), and intubation was performed by touch with the aid of a curved metal introducer. Although Kuhn had considered the possibility of metal tubes causing trauma to the trachea and larynx, he felt that the material made little difference, but it was realized elsewhere that the resilience of the rubber tube minimized the trauma of intubation and from this time rubber became the material of choice.

So far, endotracheal anaesthesia had been inhalational, that is, inspiration and expiration took place through a wide-bore tube, but in 1907 Barthelemy and Dufour of Nancy introduced the method of insufflation. Here a continuous flow of gases delivered by a narrow endotracheal tube ventilated the lower respiratory passages and expired gases returned to the exterior via the space between the tube and trachea. Meltzer and Auer (1909), New York physiologists, further developed the technique, and after extensive studies, they claimed that insufflation

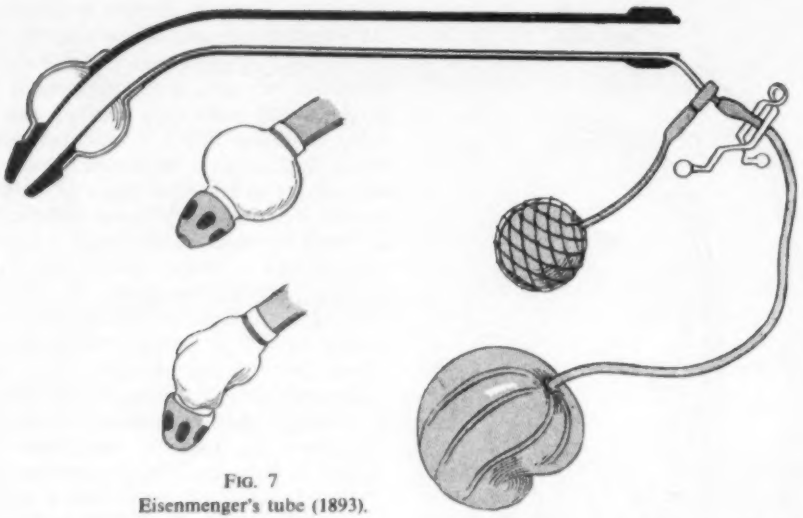

FIG. 7
Eisenmenger's tube (1893).

anaesthesia was the solution to the problem of preventing pulmonary collapse in surgical pneumothorax. They also stated that it was an efficient method of artificial ventilation and that the return flow of gases prevented aspiration. Thus insufflation anaesthesia rapidly became popular in America and Europe, but it is interesting to note that Kuhn never advocated its use, and strongly disagreed with Meltzer on its merits.

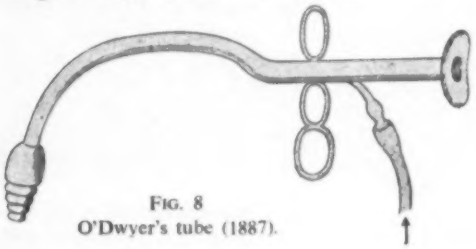

FIG. 8
O'Dwyer's tube (1887).

It was soon realized, however, by Magill and Rowbotham (Rowbotham, 1926) in this country, and by Waters and Flagg (Flagg, 1927) in America, that the claims made for insufflation anaesthesia could not all be substantiated. Firstly, it was no guarantee against aspiration, and secondly, carbon dioxide elimination was unsatisfactory. Thirdly, alarming intrapulmonary pressures could arise, if the return gas flow became obstructed. These findings caused a reversion to inhalational methods in both Europe and America.

Until 1910, the greatest hindrance to the widespread adoption of endotracheal anaesthesia had been difficulty in intubation and although Kirstein, a Berlin physician, had advocated direct laryngoscopic intubation with the Kirstein Autoscope, the idea did not receive immediate approval

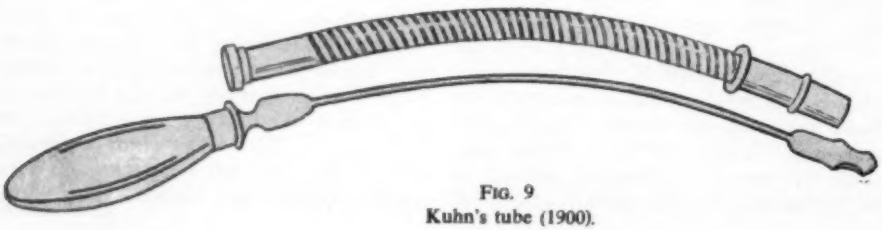

FIG. 9
Kuhn's tube (1900).

(Kirstein, 1895). This was largely because the Autoscope was a somewhat primitive instrument and the technique of laryngoscopy required practice as well as a good deal of muscular relaxation. However, by 1920 the technique was more widely accepted and its popularity was further increased by the improved laryngoscope introduced by Chevalier Jackson in 1920. This resulted in a wider acceptance of endotracheal methods in the next decade. Another factor which contributed to this trend was the large number of casualties from the 1914–1918 war requiring plastic surgery to the head and neck. It was at this time that Magill and Rowbotham who were working with the British army plastic unit, played a prominent part in the development of endotracheal methods. Rowbotham designed a wide-bore tube with an inflatable pharyngeal cuff and double inflating bellows, and Magill designed a similar orotracheal tube but with a tracheal cuff. He also designed a nasotracheal tube which was thin-walled because this afforded a larger lumen and because the nasotracheal curve, being more gradual than the orotracheal one, made the tube less likely to kink (Rowbotham and Magill, 1921).

So far, the inflatable cuff had been less popular than the pharyngeal sponge, largely because it was cumbersome and had presented manufacturing difficulties, but after the latter had been overcome it became widely used. In 1928, Guedel and Waters (1931) reintroduced the detachable inflatable cuff previously designed by Trendelenburg (1871), Eisenmenger (1893), and Dorrance (1910).

The next evolutionary phase of intubation was largely governed by the anaesthetic management of patients undergoing thoracic surgery. By 1920 the problem of paradoxical respiration in surgical pneumothorax had been solved by the use of controlled ventilation. Excessive bronchial secretions were a potential hazard, but this was mitigated by the use of posture with suction and by the employment of more rigorous pre-operative physiotherapy. Problems remaining were the prevention of transbronchial spillover and difficulties of ventilation in such cases as valvular pneumothorax, bronchial fistula and tension cyst. The solution depended on isolating the respiratory passages of one lung from those of the other and this entailed either bronchial intubation or blockage. Early experimental work of this nature had been undertaken towards the end of the nineteenth century, when extensive studies were carried out on the respiratory physiology of dogs by Head (1889), Wolffberg (1892), and Werigo (1892). This manoeuvre involved endotracheal and endobronchial intubation, so Head cleverly designed a curved metal endobronchial tube with inflatable cuff attached to an endotracheal tube (fig. 10). He was thus able to study differential

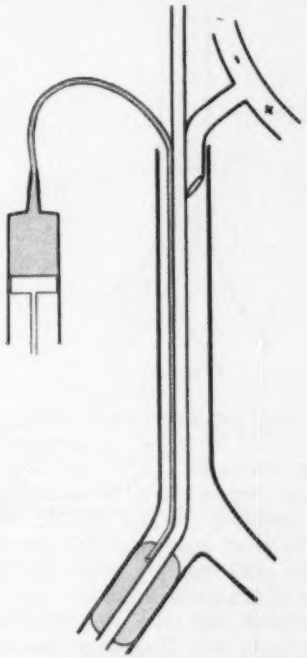

FIG. 10
Head's tube (1889).

pulmonary physiology and this is the first evidence of a double lumen tube being used. One of the first endobronchial tubes for anaesthetic use (fig. 11) was designed by Gale and Waters (1932). The tube was made of rubber and could be moulded in hot water to form a lateral curve. It was then blindly introduced into one or other bronchus. The carinal cuff, while providing an airtight seal for the intubated bronchus, also occluded the other main bronchus. A similarly styled tube, made from woven silk, was intro-

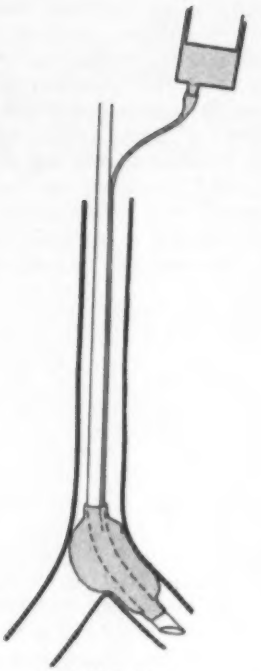

FIG. 11
Gale and Waters's tube (1931).

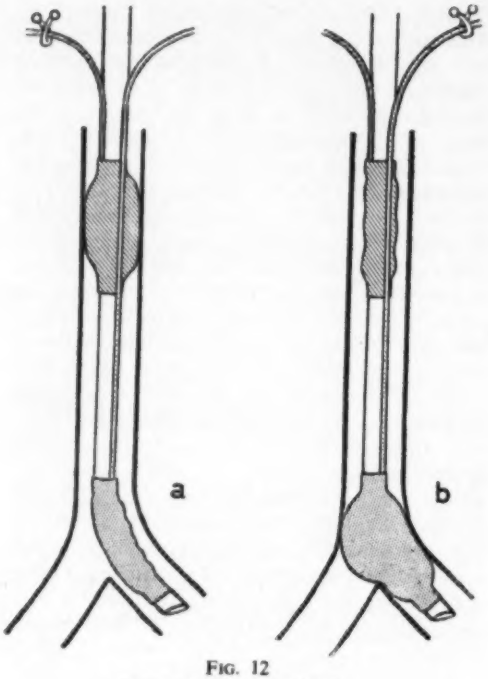

FIG. 12
Rovenstine's tubes (1936).

duced by Rovenstine (1936) (fig. 12), but both these tubes were found to be unreliable because of their instability. Having realized this, Magill (1936) designed right and left endobronchial tubes with cuffs (fig. 13). Since the right main bronchus is shorter than the left, the right tube had a terminal wire spiral to permit aeration of the right upper lobe. Originally these tubes consisted of a rubber-covered wire spiral but later they were made from rubber, except for the terminal wire spiral of the right bronchial tube.

Furthermore, Magill designed an inflatable bronchial suction blocker (Magill, 1936) (fig. 16) for cases in which endobronchial intubation was not feasible. A similar one introduced by Vernon Thompson (Rusby and Thompson, 1943) (fig. 15) has a gauze cover for the balloon thus giving the blocker a more secure hold against the bronchial wall. The stem of Magill's, however, is slim enough for it to be placed within the lumen of the endotracheal tube, so that the cuff of the tube can make an airtight seal with the trachea. In the meantime, Crafoord had also considered this problem of preventing transbronchial spill-over and in 1938 introduced the technique of endobronchial tamponage (Nosworthy, 1941). This consisted of packing off one or other main bronchus with ribbon gauze inserted through a bronchoscope (fig. 14) and then admitting gases to the other lung through an endotracheal tube.

A later development in this field is the Stüertzbecher (1953) tube (fig. 17). This is essentially an endotracheal tube with an incorporated suction stem and blocker, the length of which may be 7 cm or 9 cm. The 7-cm blocker is used for the occlusion of one or other main bronchus and the longer one for occlusion of a lobar bronchus. Introduction is performed with the aid of a laryngoscope, while the blocker is directed into one or other bronchus by means of a wire stylet.

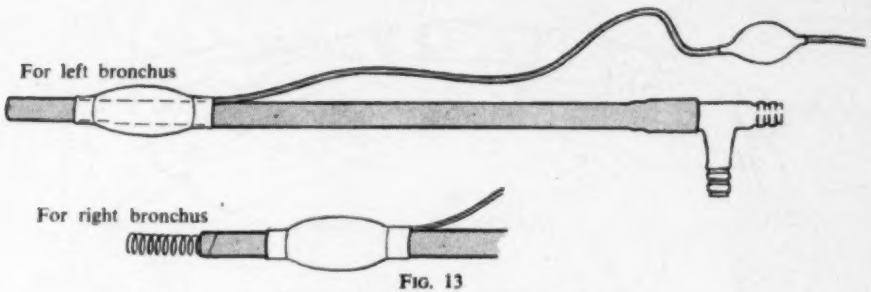

FIG. 13
Magill's endobronchial tubes (1939).

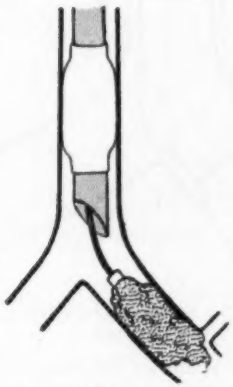

FIG. 14
Crafoord's tampon (1938).

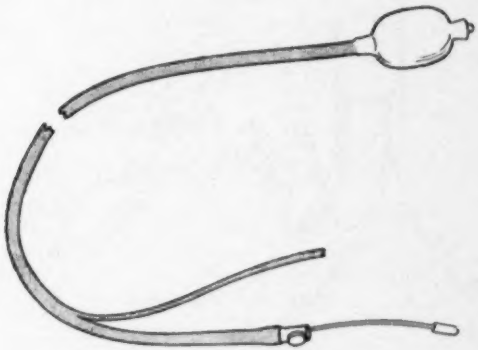

FIG. 16
Magill's endobronchial blocker (1936).

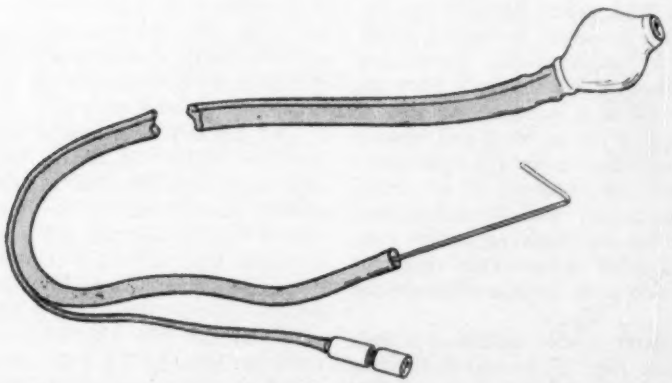

FIG. 15
Vernon-Thompson's endobronchial blocker (1943).

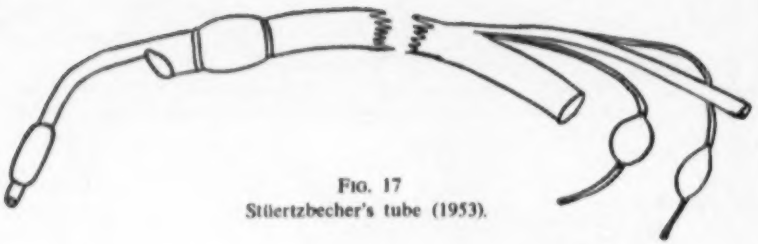

FIG. 17
Stüertzbecher's tube (1953).

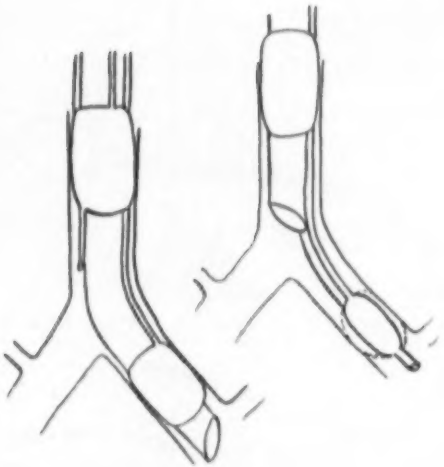

FIG. 18
Macintosh and Leatherdale's tubes (1955).

The Macintosh-Leatherdale tubes (Macintosh and Leatherdale, 1955) are of similar design (fig. 18) except that they are made of moulded rubber conforming to the shape of the trachea and bronchus and thus afford stability. They are passed with the aid of a laryngoscope only, so that bronchial intubation is blind and because of this they are of value to the less experienced anaesthetist. One tube combines a left endobronchial suction blocker with an endotracheal tube and is used for operations on the left lung, while the other is a left endobronchial tube with incorporated suction stem for operations on the right lung.

In 1954, Vellacott (1954) described a right endobronchial tube (fig. 19) for use in patients requiring right upper lobectomy when the affected lobe contains fluid, or for patients having

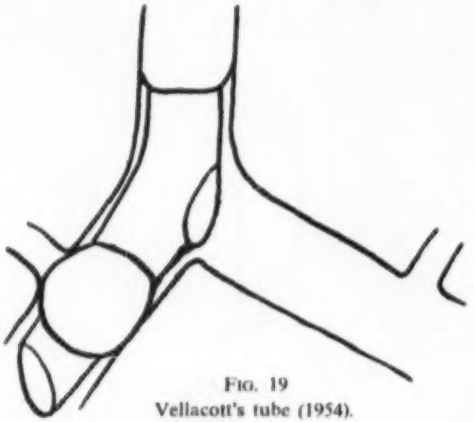

FIG. 19
Vellacott's tube (1954).

bronchopleural fistula with empyema following right upper lobectomy. The tube has an endobronchial cuff, designed to occlude the right upper lobe bronchial orifice, together with an endotracheal cuff. An orifice in the left lateral wall between the cuffs permits aeration of the left lung. The tube is a single-lumen latex one, reinforced with a spiral wire and stiffened with a malleable stylet built into the wall. It is introduced over a bronchoscope.

The difficulty in intubation of the right main bronchus without occluding the orifice of the right upper lobe bronchus has been overcome in several ways. Examples are the endobronchial tube of Gale and Waters, and Magill's right endobronchial tube. A further example is the Green-Gordon tube introduced in 1955 (Gordon and Green, 1955). This is a single-lumen right endobronchial tube with tracheal and bronchial cuffs, the latter having a slit which becomes apposed to the orifice of the right upper lobe bronchus, and communicates with the lumen of

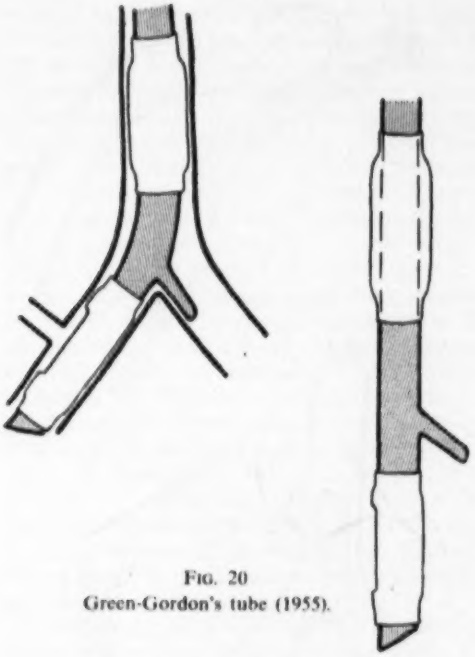

FIG. 20
Green-Gordon's tube (1955).

FIG. 21
Frenckner's tube (1934).

the tube. It is of moulded rubber, and at the tracheobronchial angle there is a hook which grasps the carina and prevents the tube being advanced too far. The tube permits aeration of the whole of the right lung, so that surgery of the left lung can be undertaken.

The use of the double-lumen tube has recently become more popular in this country, because it affords differential pulmonary ventilation with all its concomitant benefits. As has been pointed out, the idea was probably conceived in 1889 when Head designed such a tube to study respiratory physiology in dogs. In 1934 Frenckner produced a metal double-lumen bronchoscope (fig. 21) for bronchospirometric studies and this was followed by a rubber bronchospirometric catheter designed by Zavod in 1940. An improved double-lumen catheter (fig. 22) was designed by Bjork and Carlens in 1949 (Bjork and Carlens, 1950), again for bronchospirometric studies but it has since proved of considerable value in anaesthesia for thoracic surgery. This is because it renders the air passages of one

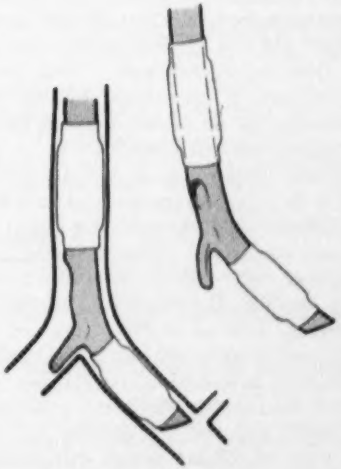

FIG. 22
Bjork and Carlens' tube (1949).

lung independent of those of the other, in that differential pulmonary ventilation is afforded and spillover of secretion is prevented. Thus it combines all the advantages of endobronchial tubes and blockers with stability, as well as the benefits conferred by differential pulmonary ventilation. The latter include more operating room within the thorax, suture of the open amputated bronchus, easier dissection of pulmonary segments, and the maximum use of available pulmonary tissue for gaseous exchange. Stability is afforded by the carinal hook, but also by the fact that the tube is moulded to the shape of the trachea and left main bronchus and occupies their whole diameter, whereas with an ordinary endobronchial tube, the tracheal part fits loosely within the trachea because its size is governed by the diameter of the bronchus and this makes for instability. Since the left main bronchus is longer than the right, the left tube is made endobronchial, while the right one terminates just above the carina. Thus the Carlens catheter is unsuitable in cases of left pneumonectomy, where it is necessary to amputate the bronchus close to the carina, because the tube must first be withdrawn from the left main bronchus and this often leads to ventilation difficulties. To obviate this complication, the writer has designed a double-lumen right endobronchial tube (fig. 23) which is essentially the combination of two previous developments, namely, the slit endobronchial cuff and the double-lumen tube (White, 1960). Here the carinal hook is even more important because it ensures the correct relationship between the slit of the cuff and the orifice of the right upper lobe brochus.

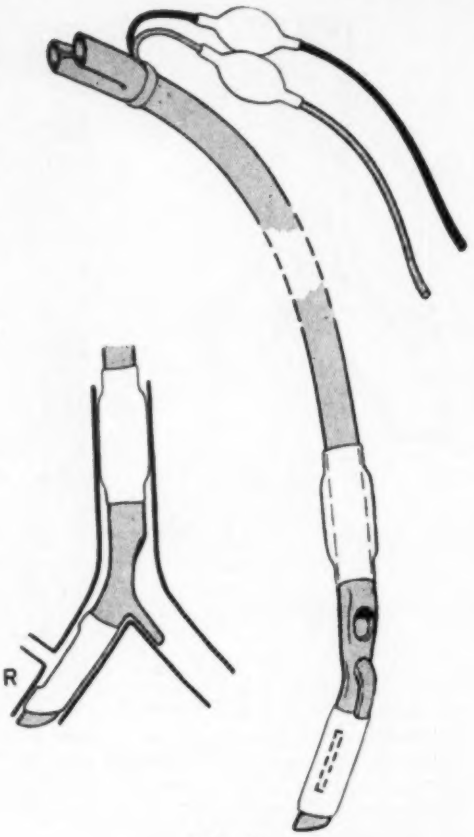

FIG. 23
The author's double-lumened right endobronchial tube (1960).

Occlusion by kinking is not an uncommon complication of intubation, and various tubes have been designed to overcome this difficulty. As mentioned previously Kuhn invented a metal endotracheal tube (fig. 9) in 1900 to prevent kinking, and the thin metal wall also afforded a large lumen. Trauma to the larynx and trachea caused metal tubes to fall into disuse, until Flagg introduced a new one in 1929. This was followed by the Coryllos McKesson tube (Coryllos, 1932, 1933) and the Woodbridge tube (1934). These were of similar design except that they had various lengths of flexible wire spiral to negotiate the pharyngeal curve. In 1954, Ballantine and Jackson designed a flexometallic tube which is simply a latex-covered wire spiral in which the tracheal end is cut at right angles to avoid occlusion of the orifice by the side wall of the trachea or bronchus. The Oxford tube introduced by Alsop in 1955 has a reinforced pharyngeal portion and is moulded to a right angle. The reinforcement reduces the possibility of kinking and the shape of the tube helps it to maintain a constant position.

From this brief and general survey, it would seem that the development of endotracheal and endobronchial tubes has followed a somewhat erratic course, and been largely dependent on

surgical requirements. Vesalius (1542) had shown advanced ideas, for not only had he appreciated the hazards of thoracotomy but had overcome them by employing controlled ventilation with an endotracheal tube. Further development was stimulated in the mid-eighteenth century when attention was drawn to the inefficient resuscitative measures prevailing at the time, and about forty years later to the high incidence of postoperative aspiration pneumonia. Another century passed before the problem of surgical pneumothorax came into prominence, and then, towards the end of the nineteenth century, the value of endotracheal tubes for smooth abdominal surgery and the removal of secretions slowly became recognized. Insufflation anaesthesia then became popular as an alternative solution to the problem of pulmonary collapse in surgical pneumothorax, but at the beginning of this century there was a reversion to inhalational methods. Since that time, further advances have been aimed to meet the requirements of anaesthesia for thoracic surgery as well as to minimize some of the hazards of endotracheal intubation.

Finally, many tubes have not been mentioned because the purpose of this article is, firstly, to emphasize those which have punctuated development and, secondly, to stress the influencing factors.

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